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D4.2 Operating Cost Analysis

Organization name of lead contractor for this report: **Institute of Aviation**

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Dissemination		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	**X**
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Errata

The following errors were found in this report
- SFC of Grob should be lower by about 15%
- Navigation fees were calculated for constant distance instead of many.
- Power of Jetstream 32 was underrated (should be higher by 34%) what impacted its performance.

These errors are fixed and results are presented in the report “EPATS aircraft missions requirements” (**EP D4.1-MissionReq)**
- The price of Jetstream was probably estimated as too low.

TABLE of CONTENTS

1 INTRODUCTION

1.1 GOALS

The goal is a direct operating cost (DOC) analysis. This is the primary parameter which influences travel cost. The knowledge of DOC structure and its sensitivity to particular components is necessary to answer the question: how to reduce costs of flying and increase accessibility of air transport.

„Engineering is done with numbers.
Analysis without numbers is at best,
only an opinion”

Paul Torgersen
Virginia Polytechnic Institute
and State University

1.2 AIRPLANE PROGRAM and LIFE CYCLE COST

An airplane program is name of airplane evolution from design to manufacturing, operational and eventually disposal. An exemplary program can be divided into several phases:

1. Planning and Conceptual Design
2. Preliminary Design and System Integration
3. Detailed Design and Development
4. Manufacturing and Acquisition
5. Operation and Support
6. Disposal

The time elapse during this six phases is called airplane life cycle. And cost connected with them are called life cycle cost (LCC) and can be broken down as follows:

1. C_{RDTE} - research, development, test and evaluation cost
2. $C_{ACQ}=C_{MAN}+C_{PRO}$ – acquisition cost composes of manufacturing cost and manufacturer profit
3. C_{OPS} - operating cost
4. C_{DISP} - disposal cost

Thus LCC equals:

$$LCC = C_{RDTE} + C_{ACQ} + C_{OPS} + C_{DISP}$$

This report takes under consideration operating cost only.

2 OPERATING COSTS

Total operating cost (TOC) is cost incurred while operating the airplane. Usually it is expressed in €/*km or €/hr (often per passenger). In general TOC are divided in two parts: Direct Operating Cost (DOC) and Indirect Operating Cost (IOC), ref 2.1.

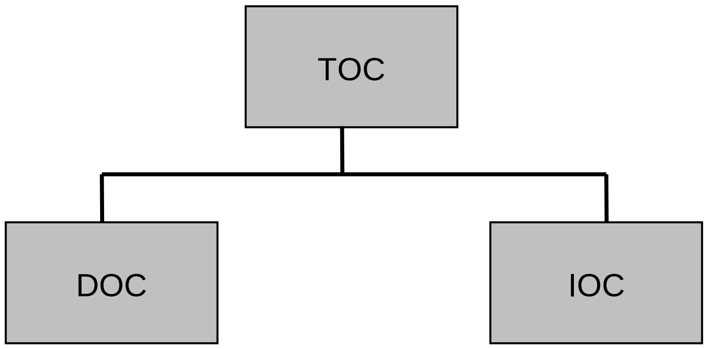


Fig. 2. 1 Operating Cost structure

2.1 DIRECT OPERATING COST (DOC) STRUCTURE

Direct Operating Cost is a part of Operating Cost which depends strongly on engineers and designers. DOC consists of several components:

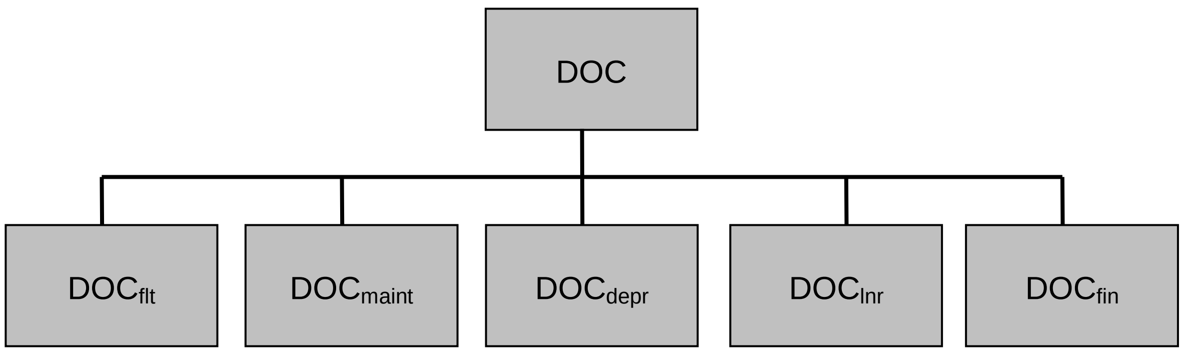


Fig. 2. 2 Direct Operating Cost structure

where:

- DOC_{flt} - cost of flying
- DOC_{maint} - cost of maintenance
- DOC_{depr} - cost of depreciation
- DOC_{lnr} - cost of landing and navigation fees and registry taxes
- DOC_{fin} - cost of financing

2.1.1 DOC of Flying

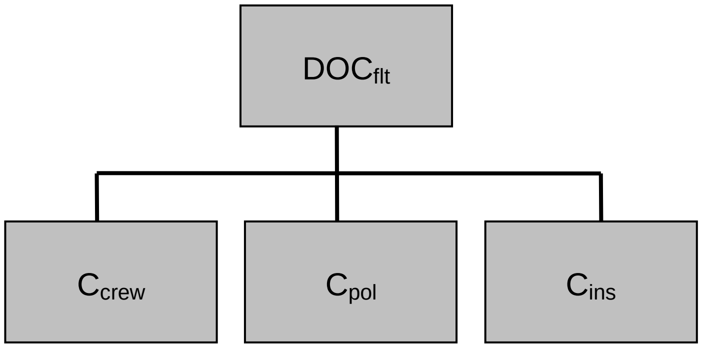


Fig. 2. 3 DOC of flying structure

where:

C_{crew} - cost of crew
C_{pol} - cost of fuel, oil and lubricants
C_{ins} - cost of the airframe insurance

2.1.2 DOC of Maintenance

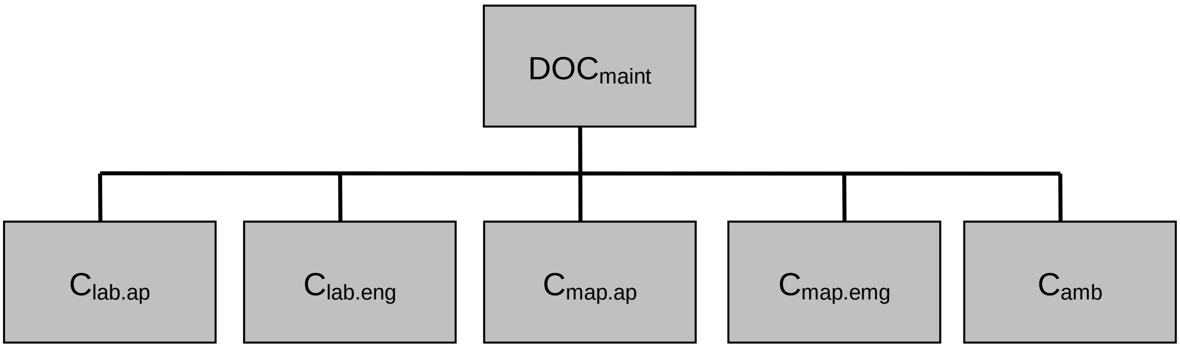


Fig. 2. 4 DOC of maitenance structure

where:

$C_{lab.ap}$ - labour cost of airframe and systems (other than the engines)
$C_{lab.eng}$ - labour cost of engine(s)
$C_{map.ap}$ - the aiframe and system (other than the engines) maintenance material cost
$C_{map.emg}$ - the engine(s) maintenance material cost
C_{amb} - the applied maintance burden

2.1.3 DOC of Depreciation

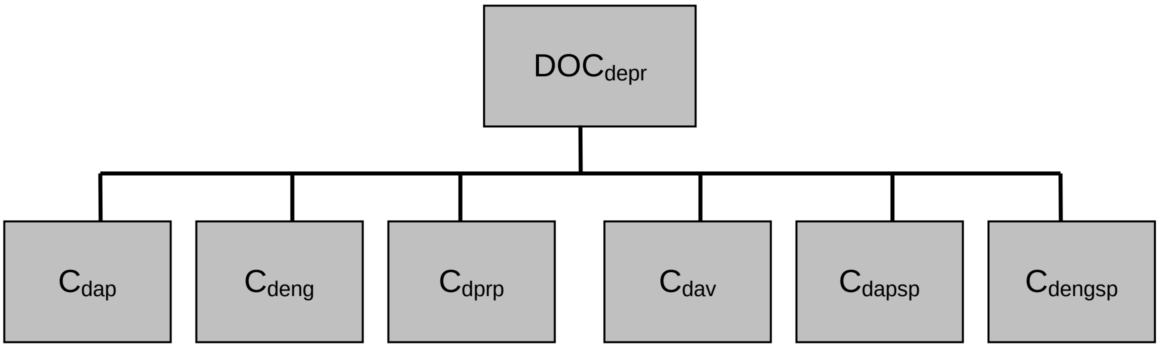


Fig. 2. 5 DOC of depreciation structure

where:

- C_{dap} - cost of airframe depreciation (airplane without engines, propellers, avionics systems and spare parts)
- C_{deng} - cost of engines depreciation
- C_{dprp} - cost of depreciation of propellers
- C_{dav} - cost of avionics systems depreciation
- C_{dapsp} - cost of depreciation of airplane spare parts
- C_{dengsp} - cost of depreciation of engines parts

2.1.4 DOC of Landing and Navigation Fees and Registry Taxes

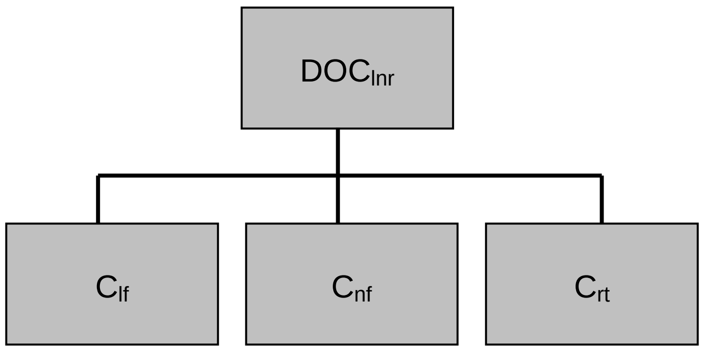


Fig. 2. 6 DOC of Landing and Navigation Fees and Registry Taxes

where:

- C_{lf} - cost of landing fees
- C_{nf} - cost of navigation fees
- C_{rt} - cost of registry taxes

2.1.5 DOC of Financing

Fig. 2. 7 DOC of financing

where:

DOC_{fin} - cost of financing

2.2 INDIRECT OPERATING COST (IOC) STRUCTURE

The Indirect Operating Cost varies significantly from one operator to another. The airplane designers have very little influence on these costs. IOC consists of several components:

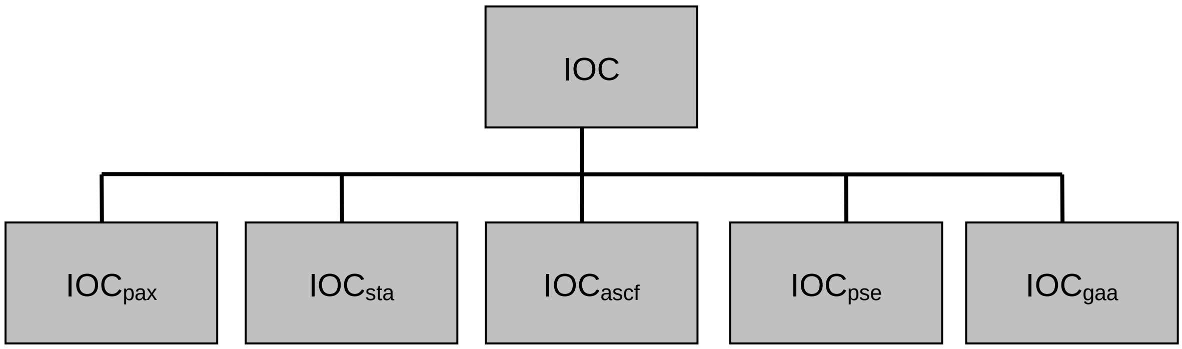


Fig. 2. 8 IOC structure

where:

IOC_{pax} - cost of passengers services
IOC_{sta} - cost of maintaining and depreciation ground equipment and ground facilities
IOC_{ascf} - cost of airplane and traffic servicing, control and freight
IOC_{pse} - cost for promotion, sales and entertainment
IOC_{gaa} - cost of general administrative expenses

2.2.1 IOC of Passengers Services

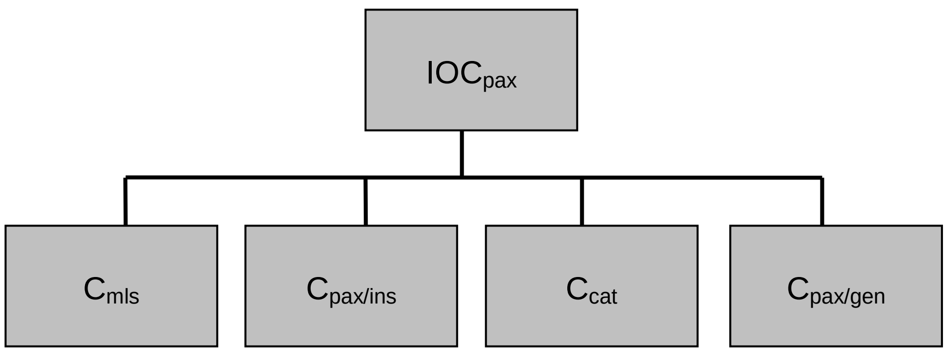


Fig. 2. 9 IOC of passenger services structure

where:

C_{mls} - cost of meal services
$C_{pax/ins}$ - cost of passengers insurance

C_{cat} - cost of cabin attendants
$C_{pax/gen}$ - cost associated with the following items:

- passenger handling
- passenger baggage handling
- sales and reservations
- security
- miscellaneus passenger costs

2.2.2 IOC of Station Operation

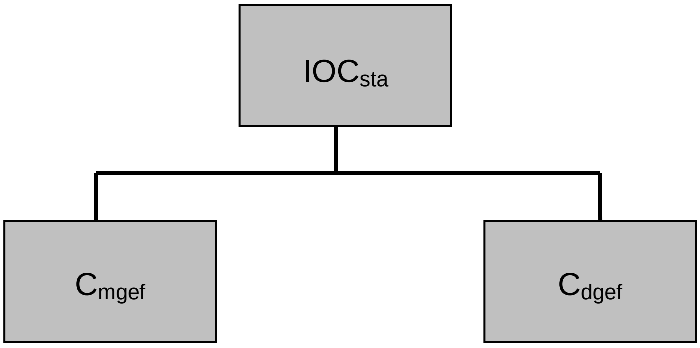


Fig. 2. 10 IOC of station operation structure

where:

C_{mgef} - cost of maintaining ground equipment and facilities
C_{dgef} - cost of depreciation of ground equipment and facilities

2.2.3 IOC of Airplane Service, Control and Freight

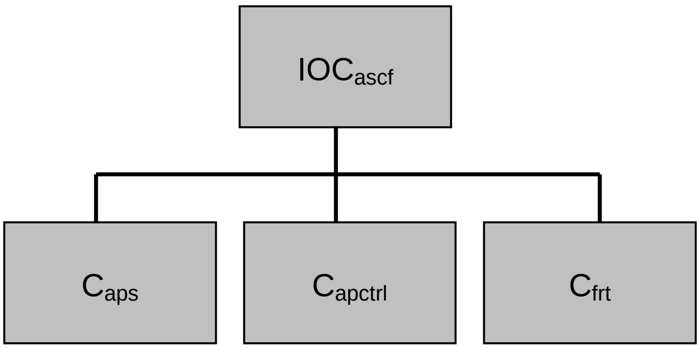


Fig. 2. 11 IOC of airplane service, control

where:

C_{aps} - cost of airplane service
C_{apctrl} - cost of airplane control (ground maneuvers)
C_{frt} - cost associated with handling freight

2.2.4 IOC of Promotion, Sales and Entertainment

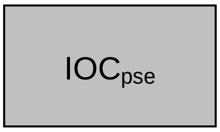


Fig. 2. 12 IOC of promotion, sales and entertainment

where:

IOC_{pse} - consist of
- o commisions to travel agencies
- o publicity and advertising campaigns
- o entertainment

2.2.5 IOC of General and Administrative Cost

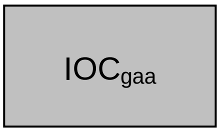


Fig. 2. 13 IOC of general and administrative cost

where:

IOC_{gaa} - consist of
- o cost of requirements for administrative and accounting personel as well as for their facilities commisions to travel agencies
- o cost requirements for corporate staffers and their facilities

3 METHODS of OPERATING COST CALCULATIONS

4 DR. ROSKAM'S METHOD of DIRECT OPERATING COST

The method presented below based on "Airplane Design, part VIII: Airplane Cost Estimation: Design, Development, Manufacturing and Operating" by Dr. Jan Roskam; Ref. [1].

4.1 BASIC DEFINITIONS and ASSUMPTIONS

Mission profile is depicted on fig. 4.1.

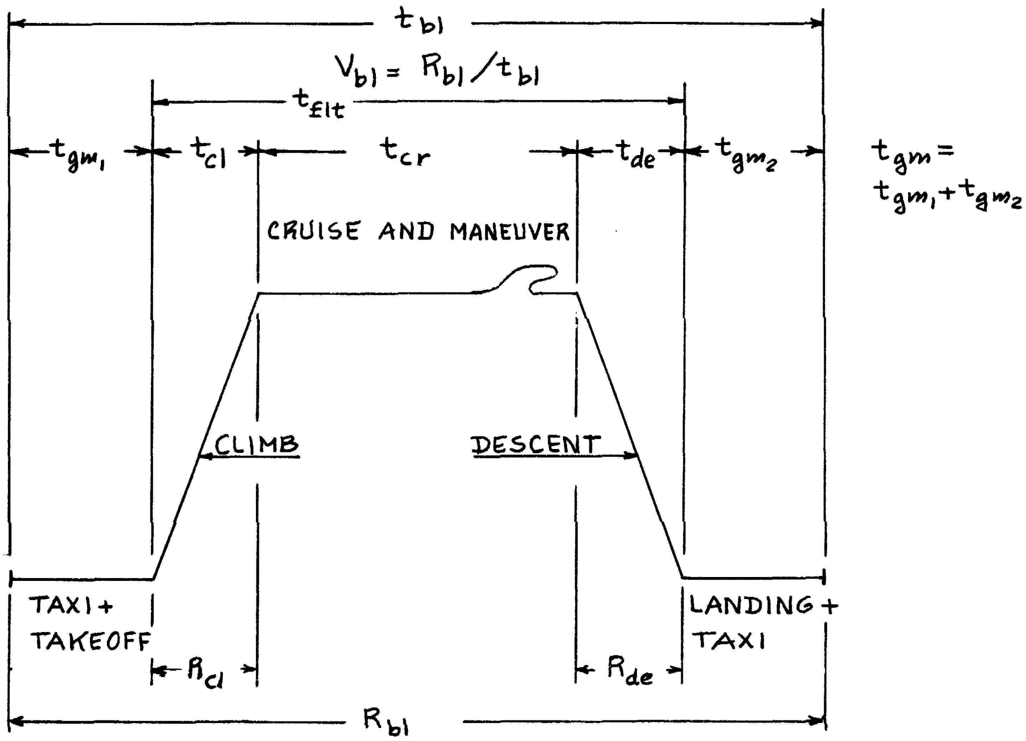


Fig.4. 1 Mission profile

where:

- R_{bl} - block distance (great circle distance between origin-destination points)
- t_{bl} - block time

$$t_{bl} = t_{gm} + t_{cl} + t_{cr} + t_{des}$$

- t_{gm} - time spent in ground maneuvers, such as pulling away from the gate, taxiing to the active runway, takeoff run, landing ground run, and taxiing to the gate
- t_{cl} - time required to climb and to accelerate to cruise condition
- t_{cr} - time spent in cruise
- t_{cl} - descent time

Time of ground maneuvers, in hours:

$$t_{gm} = 0.51 \cdot 10^{-6} \cdot W_{TO} + 0.125$$

Time due to air traffic control maneuvers (ATC), in hours:

$$t_{man} = 0.25 \cdot 10^{-6} \cdot W_{TO} + 0.0625$$

Figure 4.2 presents both, ATC and ground manevuering times, in minutes

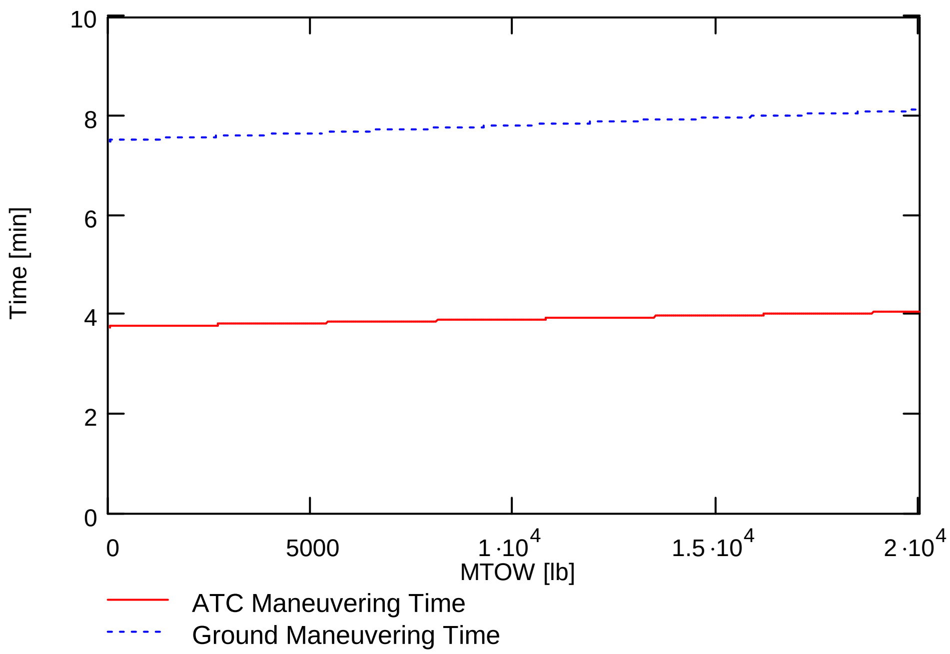


Fig.4. 2 Time of ATC and ground maneuvers (in minutes).

In facts, great circle distance cannot usually be flown in straight line. Factors 1.06 (for domestic operations) and 1.01 (for international operations) should be used.

$$t_{cr} = \frac{(1.06 \cdot R_{bl} - R_{cl} - R_{de} + R_{man})}{V_{cr}} \qquad t_{cr} = \frac{(1.01 \cdot R_{bl} - R_{cl} - R_{de} + R_{man})}{V_{cr}}$$

R_{cl} - distance cover during climb
R_{de} - distance cover during descent
R_{man} - distance cover during ATC maneuvering:

$$R_{man} = V_{man} \cdot t_{man}$$

Notes!

There is an inconsistence here. Dr. Roskam proposes to assume ATC maneuvering speed as follows:

- 250 kts above FL100
- V_{cr} below FL100

Simultaneously he treats it as cruise speed in the equation describing cruise time. Moreover such arbitrary assumed value of 250 kts could not be reach by several airplanes.

Authors' solution of these problems is:

use $t_{bl}= t_{gm}+t_{cl}+t_{cr}+t_{man}+t_{cl}$ instead of $t_{bl}= t_{gm}+t_{cl}+t_{cr}+t_{cl}$

ATC maneuvering speed equals an average speed during descent. This way is better. It allows to take under consideration deceleration during descent and approach before landing. Distance cover:

$$R_{man}=V_{man}*t_{man}$$

V_{bl} -block speed

$$V_{bl} = \frac{R_{bl}}{t_{bl}}$$

t_{flt} – flight time:

$$t_{flt}= t_{cl} + t_{cr}+t_{man}+ t_{des}$$

Thus, oryginally flight speed:

$$V_{flt} = V_{cr} \cdot \frac{T_{cr}}{T_{flt}}$$

however counting using speed definition (distance/time) we have:

$$V_{flt} = \frac{1.06 \cdot R_{cr} + \left(R_{vh} + R_{des} + R_{man}\right)}{T_{flt}}$$

Each of these two equations gives different result. We decided to use second as more precise and reliable (speed definition).

There are dependences between: cruise, flight and block speed:

$$V_{cr} > V_{flt} > V_{bl}$$

Lacking current cost and prices it is possible to estimate them. Estimates for cost magnitudes are usually given in “ten years dollars” and can be calculated as follows:

$$Cost = Cost_{1989} \cdot \frac{CEF}{CEF_{1989}}$$

$Cost_{1989}$	- cost magnitudes in 1989 - known
Cost	- cost magnitudes in 2007 - unknown,
CEF_{1989}	- cost escalation factor for year 1989 ,
CEF	- cost escalation factor for year 2007,

Reference [4] contains necessary cost escalation data.

4.2 COST of FLYING: DOC_{flt}

Cost of flying equals:

$$DOC_{flt} = C_{crew} + C_{pol} + C_{ins}$$

4.2.1 Cost of Crew

$$C_{crew} := \sum_{j=0}^{2} \left[n_{c_j} \cdot \frac{(1+K)}{V_{bl}} \cdot \frac{SAL_j}{AH} + \frac{TEF}{V_{bl}} \right]$$

n_c - number of crew members of each type j:
1. captain, 2. co-pilot, 3.flight engineer.

K - a factor which accounts for:
- vacation pay
- training cost
- crew premium, insurance
- payroll tax

This factor may vary from one operator to another. Lacking detailed data it is suggested to use: K=0.26

SAL - the annual salary paid to a crew member of type j:
1. captain, 2. co-pilot, 3. flight engineer.

AH - number of flight hours per year for particular crew members

	Jets	Pistons and Turboprops
Domestic operations	800	900
International operations	750	850

Tab. 4. 1 The annual work time limits of pilots.

TEF - Travel Expense Factor – travel expense factor (e.g. hotels)

	TEF [1990 USD]
Domestic operations	7.0 per bl.hr
International operations	11.0 per bl.hr

Tab. 4. 2 Travel expense factors.

Note! Data for year 1990.

4.2.2 Cost of Fuel Oil and Lubricants

Costs of fuel, oil and lubricants could be described by one equation:

$$C_{pol} := 1.05 \cdot \frac{W_{F.bl}}{R_{bl}} \cdot \frac{FP}{FD}$$

$W_{F.bl}$ - fuel weight (block fuel)
FP - fuel price [$/gal]
FD - fuel density [lbs/gal]:

Aviation Petroleum	
	lbs/gal
Kerosene	6.70
JP-1	6.65
JP-3	6.45
JP-4	6.55
JP-5	6.82
Jet-A	6.74

Aviation Gasoline	
	lbs/gal
grades 100/130	6
grades 100/130	5.9
grades 100/130	5.8

4.2.3 Cost of Airframe Insurance

$$C_{ins} = f_{ins.hull} \cdot \frac{AMP}{U_{ann.bl} \cdot V_{bl}}$$

$f_{ins.hull}$ - annual hull insurance rate per airplane price.
AMP - airplane market price
$U_{ann.lb}$ – annual utilization in block hours

4.3 COST of MAINTENANCE : DOC_{maint}

Cost of maintenance is broken down as follows:

$$DOC_{maint} = C_{lab\_ap} + C_{lab\_eng} + C_{mat\_ap} + C_{mat\_eng} + C_{amb}$$

4.3.1 Labour Cost of Airframe and Systems (other than engines)

Number of airframe and systems maintenance manhours per flight hour for particular airplane types can be estimated by:

$$MHR_{map.flt} = \begin{cases} 1.7 + \frac{0.067 \cdot W_A}{1000} & \text{if} \quad case = \text{"p-prop"} \\ 3.0 + \frac{0.067 \cdot W_A}{1000} & \text{if} \quad case = \text{"t-prop"} \\ 3.0 + \frac{0.067 \cdot W_A}{1000} & \text{if} \quad case = \text{"jet"} \end{cases}$$

where:

W_A - airframe weight (without engines):

$$W_A = W_E - N_e \cdot W_{eng}$$

W_E - empty weight
N_e - number of engines
W_{eng} - engine weight

Number of maintenance manhours per flight hour can be converted to number per block hour:

$$MHR_{map.bl} = MHR_{map.flt} \cdot \frac{t_{flt}}{t_{bl}}$$

thus cost of labour per block hour equals:

$$C_{lab\_ap} = 1.03 \cdot MHR_{map.bl} \cdot \frac{R_{l.ap}}{V_{bl}}$$

$R_{l.ap}$ – airplane maintenance labour rate per manhour [$/hr]
(e.g. mechanic with A/P)

4.3.2 Labour Cost of Engines

Attained period between engine overhaul:

$$K_{H.em} = \begin{cases} \left[0.076 \cdot \left(\frac{H_{em}}{100}\right) + 0.164\right] & \text{if case = "p-prop"} \\ \left[0.021 \cdot \left(\frac{H_{em}}{100}\right) + 0.769\right] & \text{if case = "t-prop"} \\ \left[0.021 \cdot \left(\frac{H_{em}}{100}\right) + 0.769\right] & \text{if case = "jet"} \end{cases}$$

H_{em} - time between overhauls (TBO) [hours].

Number of engine maintenance manhours per block hour for particular airplane types can be estimated by:

$$MHR_{meng.bl} = \begin{cases} \left[0.0765 \cdot \left(\frac{W_{eng}}{1000}\right)^2 + 0.2495 \cdot \left(\frac{W_{eng}}{1000}\right)\right] \cdot \left(\frac{0.70}{K_{H.em}} + 0.30\right) & \text{if case = "p-prop"} \\ \left[\left(0.4956 + 0.0532 \cdot \frac{SHP_{TO}}{1000}\right) \cdot \left(\frac{1100}{H_{em}}\right) + 0.10\right] & \text{if case = "t-prop"} \\ \left[\left(0.718 + 0.0317 \cdot \frac{T_{TO}}{1000}\right) \cdot \left(\frac{1100}{H_{em}}\right) + 0.10\right] & \text{if case = "jet"} \end{cases}$$

thus cost of engine labour per block hour equals:

$$C_{lab\_eng} := 1.03 \cdot (1.3) \cdot N_e \cdot MHR_{meng.bl} \cdot \frac{R_{l.eng}}{V_{bl}}$$

$R_{l.eng}$ - engine maintenance labour rate per manhour [$/hr]
(can be used mechanic with A/P rate)

(1.3) - factor account for cycle-dependent labour (as opposed to cycle-independent labour)

4.3.3 Maintenance Material Cost of Airframe and Systems (other than engines)

Cost of airframe and system maintenance material (takes under account avionics but not engines) per block hour for particular airplane types can be estimated by:

$$C_{mat\_apblhr} = \begin{cases} \left[\left(36.0\cdot\frac{CEF}{CEF_{1989}}\cdot ATF\right) + 0.475\cdot 10^{-5}\cdot AFP\right] & \text{if case = "p-prop"} \\ \left[\left(30.0\cdot\frac{CEF}{CEF_{1989}}\cdot ATF\right) + 0.79\cdot 10^{-5}\cdot AFP\right] & \text{if case = "t-prop"} \\ \left[\left(30.0\cdot\frac{CEF}{CEF_{1989}}\cdot ATF\right) + 0.79\cdot 10^{-5}\cdot AFP\right] & \text{if case = "jet"} \end{cases}$$

ATF – Airplane Type Factor:

$$ATF = \begin{cases} 1.0 & \text{if } W_{TO} \geq 10000 \\ 0.5 & \text{if } 5000 \leq W_{TO} < 10000 \\ 0.25 & \text{if } W_{TO} < 5000 \end{cases}$$

W_{TO} - maximum takeoff weight [lbs]
AFP - Airframe Price

$$AFP = AMP - N_e\cdot C_{e.m}$$

AMP - Airplane Market Price
$C_{e.m}$ - engine price

4.3.4 Maintenance Material Cost for Engines

Maintenance material cost per engine per block hour can be estimated from:

$$C_{mat\_engblhr} = \begin{cases} \left[0.0004272\cdot\left(\frac{C_{e.m}}{1000}\right)^2 + 0.08263\cdot\left(\frac{C_{e.m}}{1000}\right)\right]\cdot\left(0.10 + \frac{0.90}{K_{H.em}}\right) & \text{if case = "p-prop"} \\ \left(5.43\cdot 10^{-5}\cdot C_{e.m}\cdot ESPPF - 0.47\right)\cdot\left(\frac{1}{K_{H.em}}\right) & \text{if case = "t-prop"} \\ \left(5.43\cdot 10^{-5}\cdot C_{e.m}\cdot ESPPF - 0.47\right)\cdot\left(\frac{1}{K_{H.em}}\right) & \text{if case = "jet"} \end{cases}$$

ESPPF - is the engine spare parts factor. It depends on manufacturer’s policy in pricing spare parts. If all engine components could be purchase at the same price as a fully assembled engine, the value of ESPPF would be 1.0. It is suggested to use ESPPF=1.5.

4.3.4 Applied Maintenance Cost Burden

To cover additional cost such as: building, lightening, heating as well as administrative cost associated with airplane maintenance it is necessary to use overhead factors:

$f_{amb.map}$ - overhead factor for applied materials cost
$f_{amb.lab}$ - overhead factor for applied labour cost

These factors depend on kind of operating activities:

	Personal	Corporate	Airlines
f_{amb_lab}	0.80 - 0.90	0.90 - 1.00	1.00 - 1.40
f_{amb_mat}	0.20 - 0.30	0.30 - 0.40	0.40 - 0.70

Tab. 4. 3 Overhead factors for applied maintenance cost.

Thus, applied maintenance cost:

$$C_{amb} := 1.03 \cdot \left[\frac{f_{amb\_lab} \cdot (MHR_{map.bl} \cdot R_{l.ap} + N_e \cdot MHR_{meng.bl} \cdot R_{l.eng}) + f_{amb\_mat} \cdot (C_{mat\_apblhr} + N_e \cdot C_{mat\_engblhr})}{V_{bl}} \right]$$

4.4 COST of DEPRECIATION: DOC_{depr}

The DOC of depreciation can be broken down as follows:

$$DOC_{depr} = C_{dap} + C_{deng} + C_{dprop} + C_{dav} + C_{dapsp} + C_{dengsp}$$

where:

C_{dap} - cost of airframe depreciation (airplane without engines, avionics systems, propellers and spars)
C_{deng} - cost of engines depreciation (without propeller)
C_{dprop} - cost of propellers depreciation
C_{dav} - cost of avionics systems depreciation
C_{dapsp} - cost of airplane spare parts depreciation
C_{dengsp} - cost of engines spare parts depreciation

Costs of depreciation strongly depend on assumed: depreciations periods and depreciation factors. Table 4.4 presents these values for particular cost components.
In column 3 there are two numbers: original/**modified** of depreciation periods. These bolded were used for calculations.

	Depreciation Period in Years		Residual Value	Depreciation Factor*	
Airframe	DP_{ap}	10 / **20**	0.15	F_{dap}	0.85
Engines	DP_{eng}	7 / **10**	0.15	F_{deng}	0.85
Propellers	DP_{prp}	7 / **10**	0.15	F_{dprp}	0.85
Avionics	DP_{av}	5 / **5**	0.00	F_{dav}	1.00
Airplane Spare Parts	DP_{apsp}	10 / **20**	0.15	F_{dapsp}	0.85
Engines Spare Parts	DP_{engsp}	7 / **10**	0.15	F_{dengsp}	0.85
* Depreciation Factor = 1 - (Residual Value/ Original Price)					

Tab. 4. 4 Depreciation: periods and factors.

Such a way does not consider utilization intensity. The authors' proposition is to calculate detailed depreciation period (data from table 4.4 are treated as maximum values):

$$DP = \frac{Resurs}{U_{ann.bl}} \le Data_{Table}$$

DP - Depreciation Period [years]
Resurs - life time [hours]
$U_{ann.bl}$ - annual utilization [block hours]

4.4.1 Cost of Airframe Depreciation (airplane without engines, avionics systems, propellers and spars)

$$C_{dap} = \frac{F_{dap} \cdot \left(AMP - N_e \cdot C_{e.m} - N_p \cdot C_{p.m} - C_{avionics.m}\right)}{DP_{ap} \cdot U_{ann.bl} \cdot V_{bl}}$$

4.4.2 Cost of Engines Depreciation (without propeller)

$$C_{deng} = \frac{F_{deng} \cdot N_e \cdot C_{e.m}}{DP_{eng} \cdot U_{ann.bl} \cdot V_{bl}}$$

4.4.3 Cost of Propellers Depreciation

$$C_{dprop} = \frac{F_{dprp} \cdot N_p \cdot C_{p.m}}{DP_{prop} \cdot U_{ann.bl} \cdot V_{bl}}$$

4.4.4 Cost of Avionics Systems Depreciation

$$C_{dav} = \frac{F_{dav} \cdot C_{avionics.m}}{DP_{av} \cdot U_{ann.bl} \cdot V_{bl}}$$

4.4.5 Cost of Airplane Spare Parts Depreciation

$$C_{dapsp} = \frac{F_{dapsp} \cdot F_{apsp} \cdot (AMP - N_e \cdot C_{e.m})}{DP_{apsp} \cdot (U_{ann.bl} \cdot V_{bl})}$$

4.4.6 Cost of Engines Spare Parts Depreciation

$$C_{dengsp} = \frac{F_{dengsp} \cdot F_{engsp} \cdot N_e \cdot C_{e.m} \cdot ESPPF}{DP_{endsp} \cdot (U_{ann.bl} \cdot V_{bl})}$$

4.5 COST of NAVIGATION and LANDING FEES and REGISTRY TAXES: DOC_{lnr}

Cost of fees and taxes is broke down a follows:

$$DOC_{lnr} = C_{lf} + C_{nf} + C_{rt}$$

There are no uniform fees price-list. Especially there are big differences between values from Ref.[1] and other (Europeans) sources. The following paragraphs present comparison of them.

4.5.1 Navigation Fees

Navigation fees depend on airplane maximum takeoff weight (MTOW) and flight distance. Fees from Ref.[1] seem to be to low. The better solution is using Eurocontrol equation:

$$C_{nav} = 2 \cdot 0.005 \cdot Distance \cdot \sqrt{\frac{MTOW}{50}}$$

On the basis of analysing available data, we decided to increase base fee per km from 0.005 to 0.01 \$. MTOW is in kg. Figure 4.3 shows results obtained using different ways of calculations.

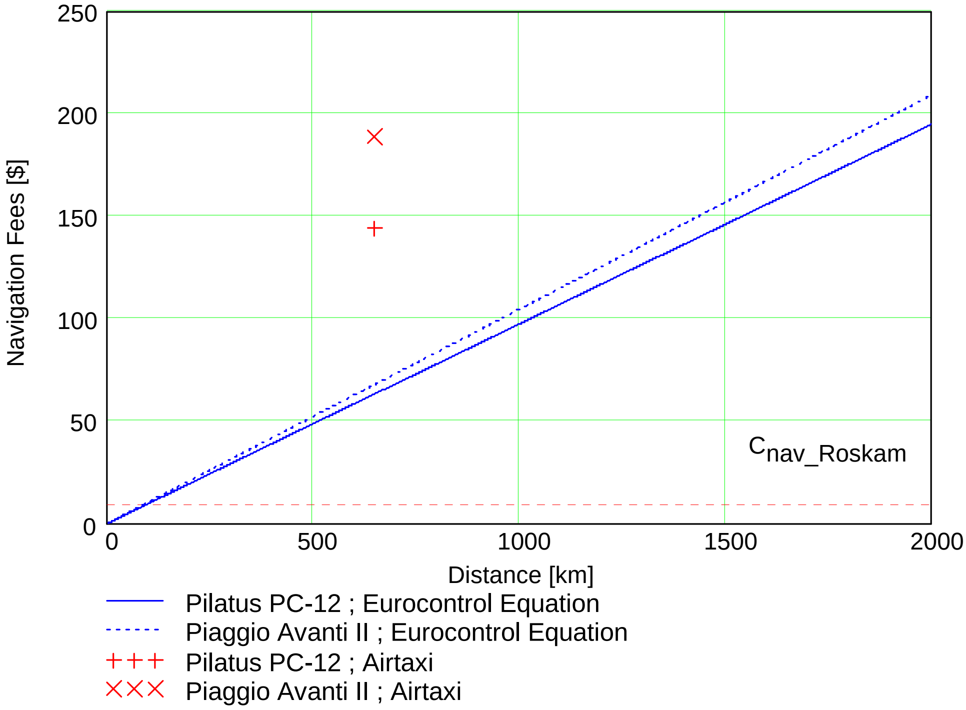


Fig.4. 3 Navigation fees - different ways of calculations.

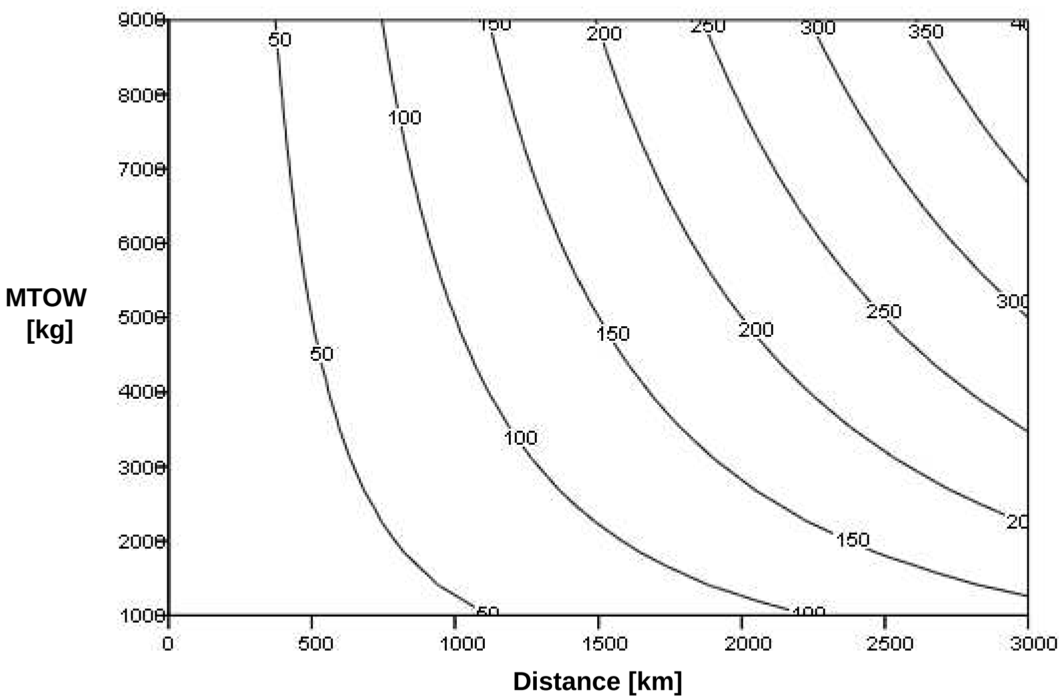


Fig.4. 4 Landing fees as a function of distance and MTOW (Eurocontrol equation)

4.5.2 Landing Fees

Landing fees depend on airplane maximum take off weight. Prices vary from one airport to another. On figure 4.5 there is a comparison of results obtained from two following equations and data from airtaxi operator.

Roskam:

$$C_{aplf} = 0.036 + 4 \cdot 10^{-8} \cdot W_{TO}$$

W_{TO} in lbs

MTOW equation:

$$C_{aplf} = \frac{10}{1000} \cdot MTOW$$

W_{TO} in kg

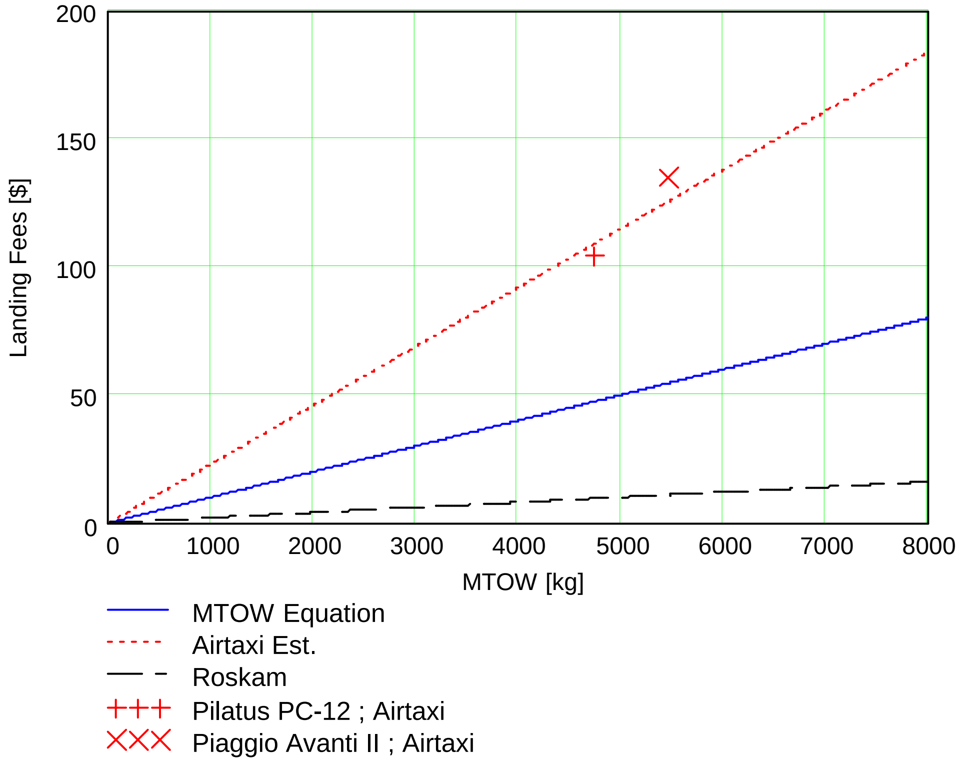


Fig.4. 5 Landing fees - different ways of calculations.

4.5.3 Registry Taxes

Lacking detailed data it is suggested to use:

$$C_{rt} = f_{rt} \cdot DOC$$

where:

f_{rt} - factor depends on airplane size:

$$f_{rt} = 0.001 + 1 \cdot 10^{-8} \cdot W_{TO}$$

4.6 COST of FINANCING: DOC_{fin}

The cost of financing the operations, depends on how an operator is financing his aircraft fleet.

$$DOC_{fin} = 0.07 \cdot DOC$$

This “rule-of-thumb” based on the observation that total financing cost typically amount to around 7% of the total DOC.

4.7 METHOD CALIBRATION

Method described above comes from 1990 (first Ref. [1] edition) and needs calibration. It has been done using available operating data of current airplanes.(Cessna Citation famili and Eclipse 500).

4.7.1 Number of Maintenance Manhours per Flight Hour

As can be seen on Fig.4.6 ratio between original and current values can reach the factor of 5 for small aircraft (for exepmle: Cessna Citation Mustang or Eclipse 500). Such huge differences were unacceptable. The corrected maintenance manhours equations are presented below:

$$MHR_{map.flt} = \begin{cases} 0.148 + \frac{0.1023}{1000} \cdot W_A & \text{if case = "p-prop"} \\ 0.262 + \frac{0.1023}{1000} \cdot W_A & \text{if case = "t-prop"} \\ 0.262 + \frac{0.1023}{1000} \cdot W_A & \text{if case = "jet"} \end{cases}$$

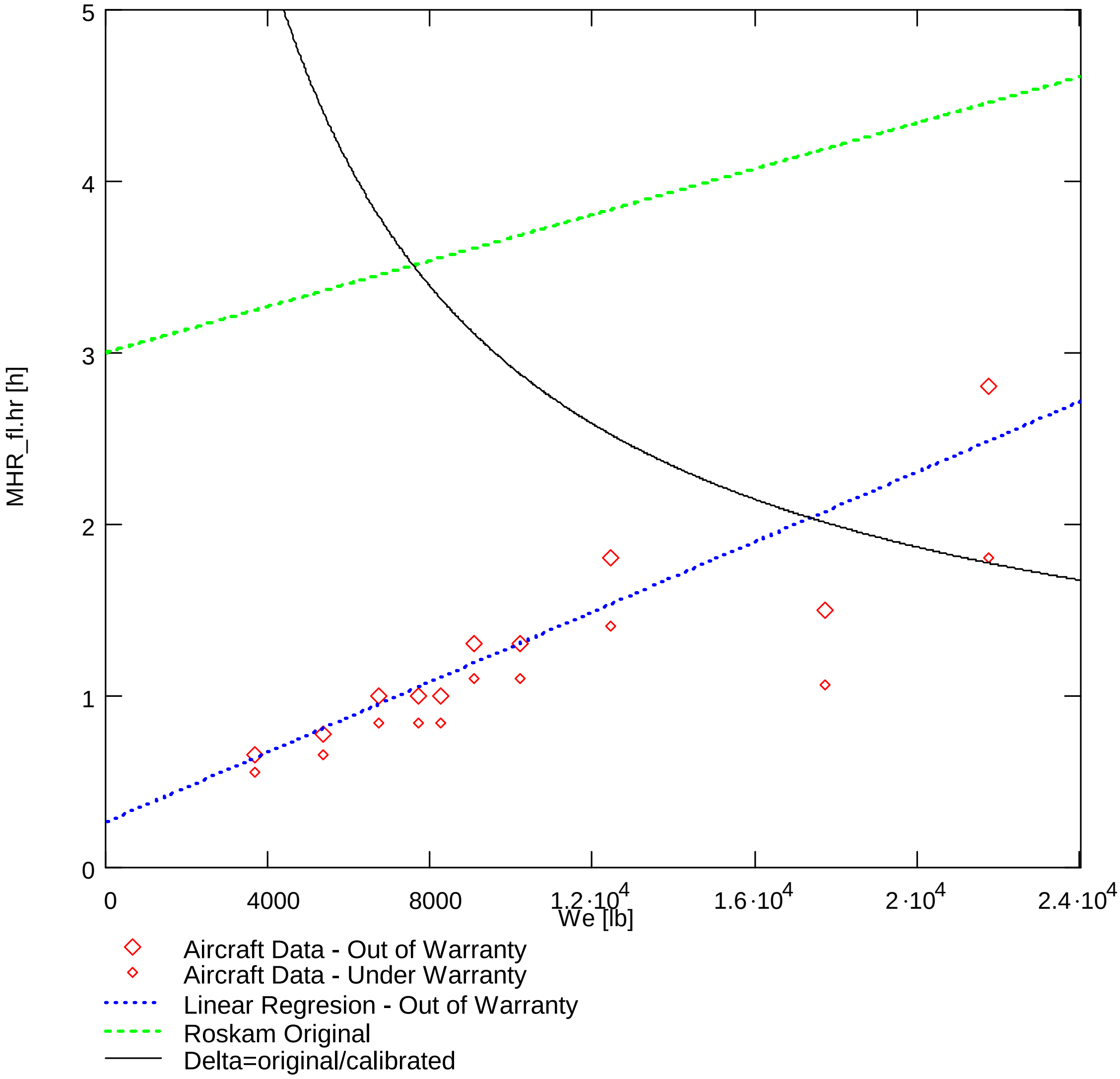


Fig.4. 6 Maintenance manhours per flight hour

4.7.2 Maintenance Material Cost of Airframe and Systems (other than engines)

Figures 4.7 and 4.8 shows comparition of maintenance parts cost: aircraft data vs calculations. Interesting are big differences between values under and out of warranty. Because in EPATS we are interested in high utilization level (to reduces services prices) calibration has been done considering out of warranty data. Aircraft cost data are expressed per flight hour, while Roskam's calculation are per block hour. Ratio between flight and block time varies, depending on airplane, distance and mission profile. For comparision purpose, we assumed, it equals 0.9 (for 500 nm).

Airplane Type Factor (ATF) also need adjustment to improve results for smallest and biggest construction:

$$ATF = \begin{cases} 1.5 & \text{if} \quad W_{TO} \geq 19000 \\ 1.0 & \text{if} \quad 5000 \leq W_{TO} < 19000 \\ 0.5 & \text{if} \quad W_{TO} < 5000 \end{cases}$$

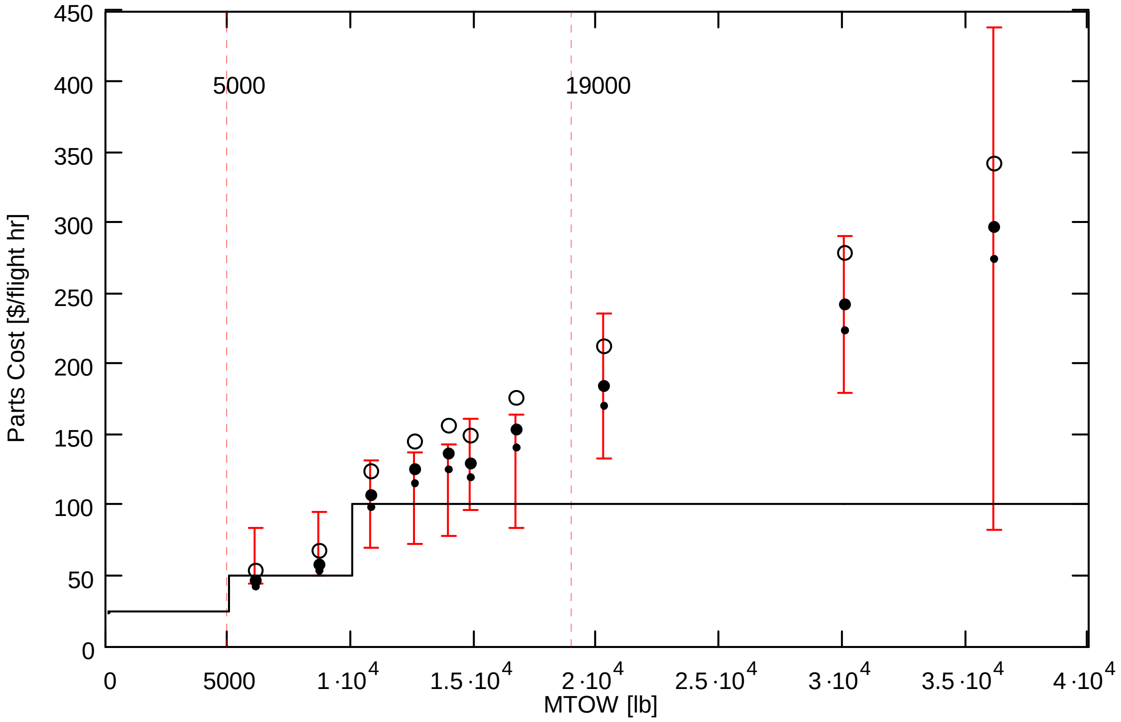


Fig.4. 7 Cost of airframe parts per flight hour (without corrections)

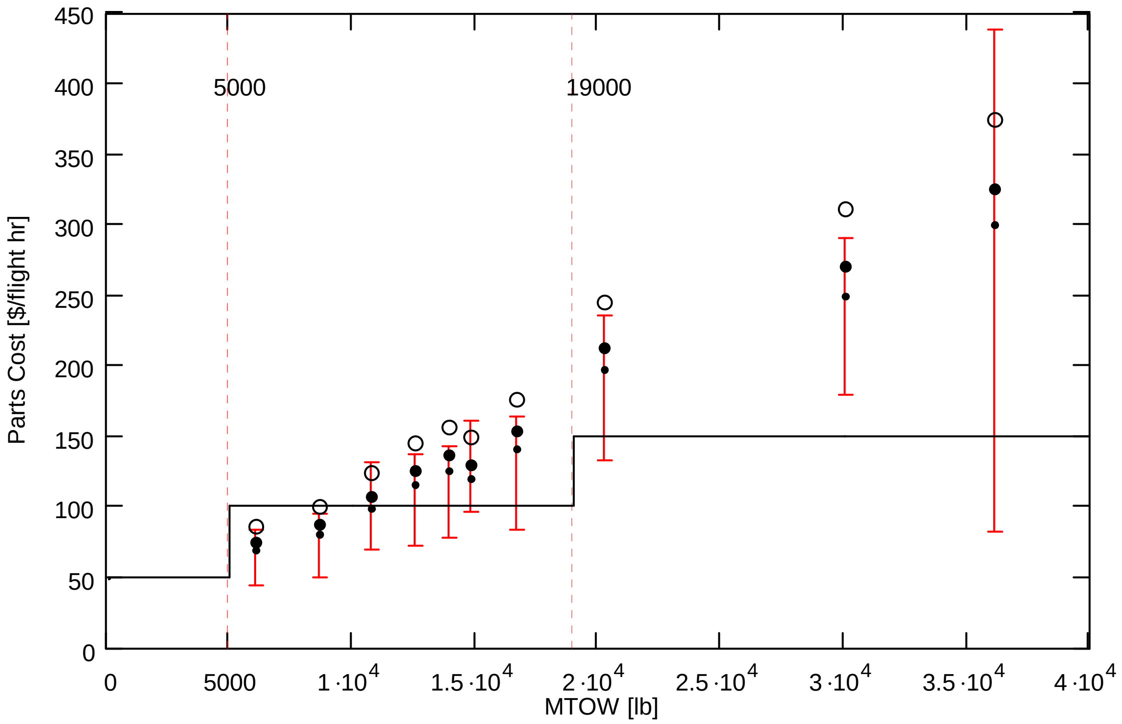


Fig.4. 8 Cost of airframe parts per flight hour (corrections applied)

4.7.3 Maintenance Labour and Material Cost for Engines

The sum of: labour, material and applied cost burden, is called "engine reserves":

$$C_{eng.res\_flhr} = C_{mat\_engflhr} + C_{lab\_engflhr} + C_{amb\_engflhr}$$

Aircraft cost data are expressed per flight hour, while Roskam's calculation are per block hour. From now we will treat them as per block hours. We also examined influence of coeficient Cycle Dependent/Independet. Figures 4.10 and 4.11.

Changing coefficient

$$C_{mat\_engflhr} = 1.03 \cdot (1.0) \cdot C_{mat\_engflhr}$$

$$C_{lab\_engflhr} = 1.03 \cdot (1.0) \cdot MHR_{meng.flhr} \cdot R_{l.eng}$$

First step to calculate engine-dependent maintenance cost is their prices update. Especially jet engines' (prices) differ much from old Roskam data. Figure 4.9 shows detailes.

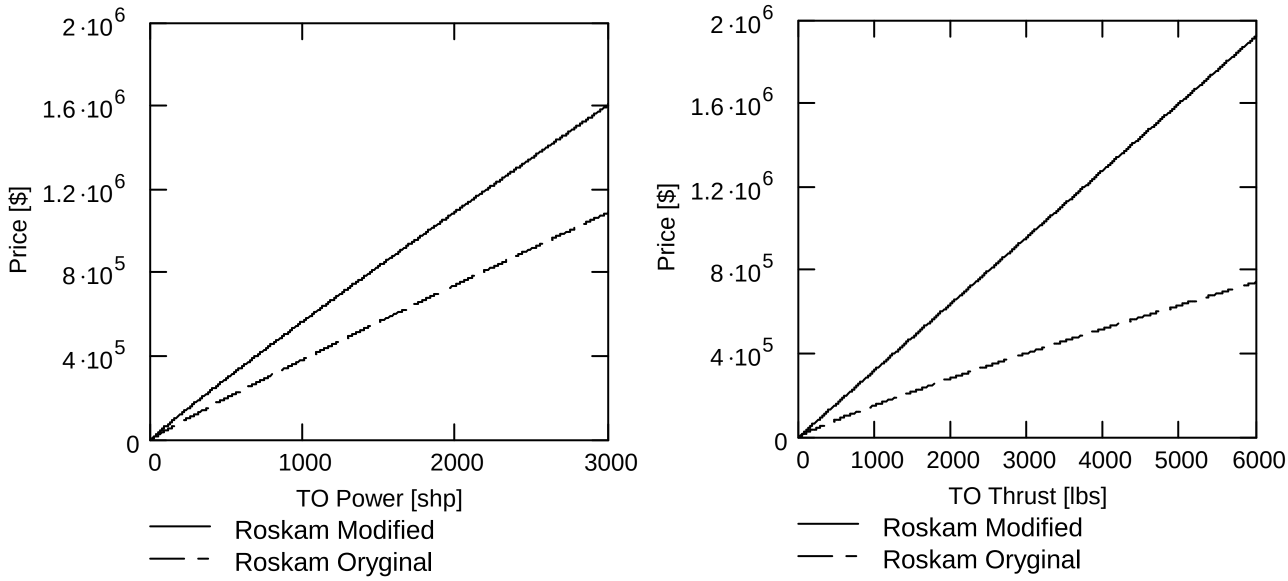


Fig.4. 9 Engines prices correction

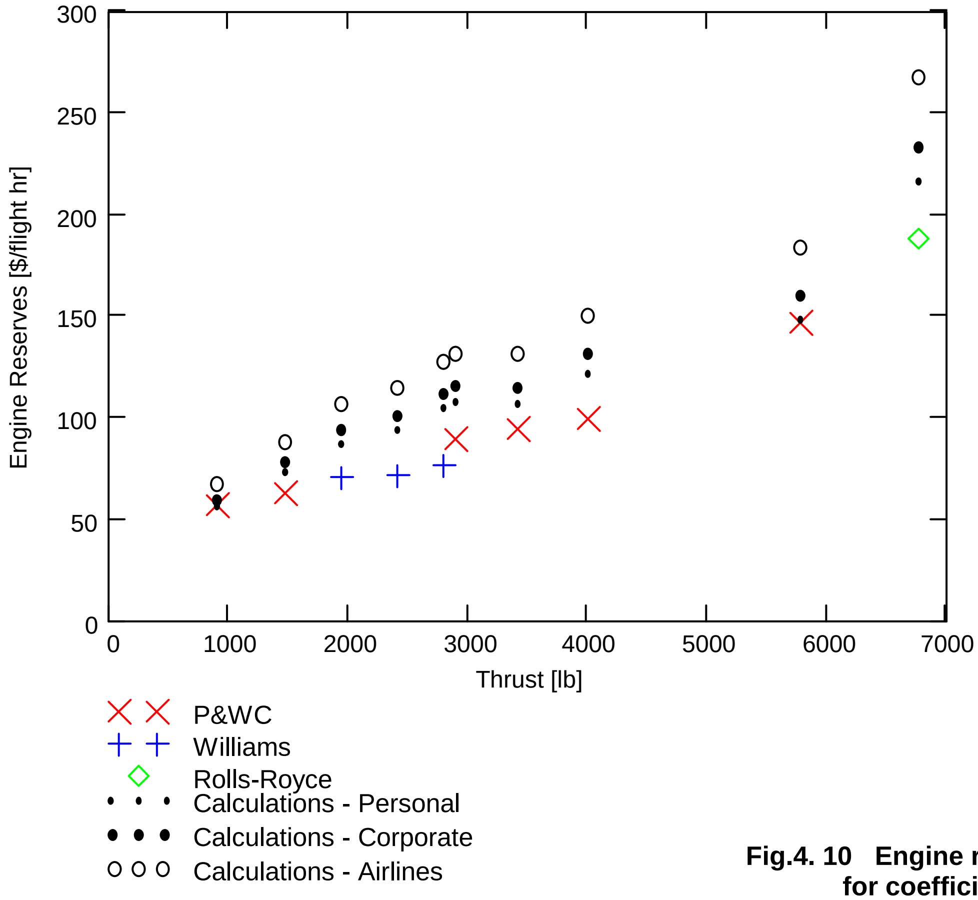


Fig.4. 10 Engine reserves for coefficient (1.3)

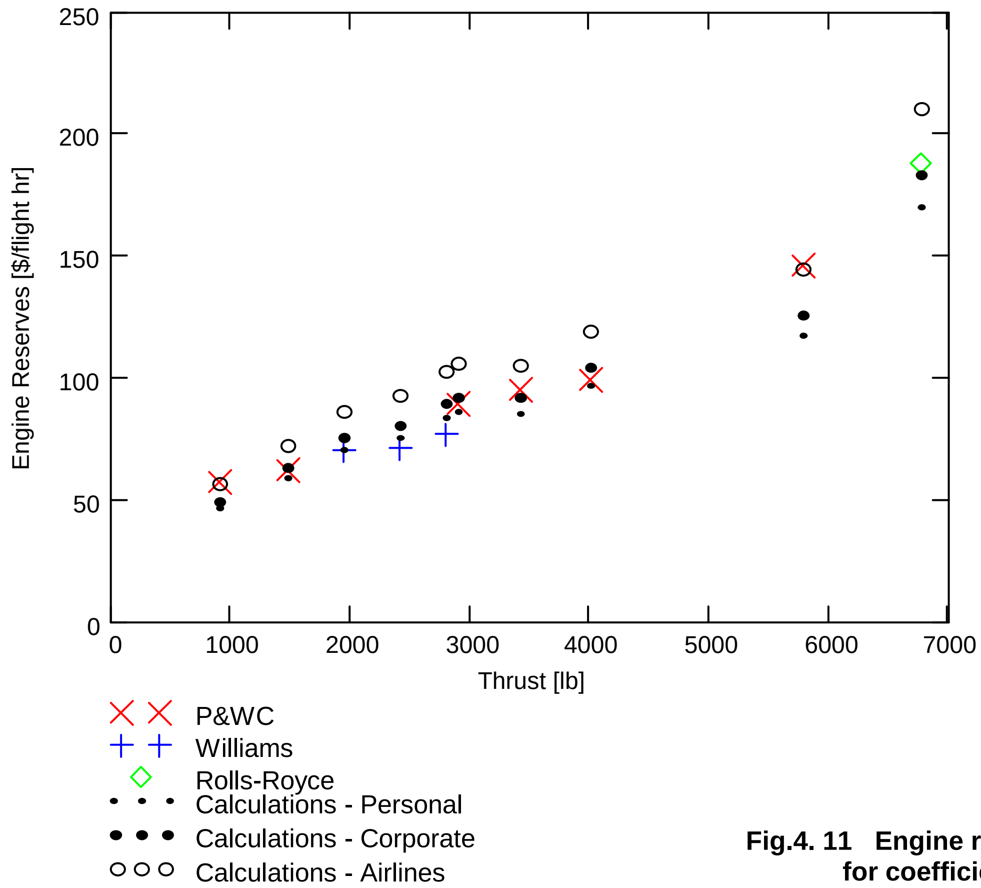


Fig.4. 11 Engine reserves for coefficient (1.0)

4.7.4 Depreciation of Airplane

Reference [2] assumes 5% as annual depreciation value for all GA airplanes. Their average utilization equals 139 flight hours (from 105 to 418). Simillarly airtaxi operators do. Such way does not take under consideration utlization intensity and different life limits (and depreciation way) for airframe, engines and avionics system.

Roskam algorithm allows for detailed spare parts cost calculation for both: airframe and engines. Therefore it is surprising to take another values for depreciation computation. Even for 200 hour per year results are higher than 5%. It seems too high. Details are presented on figure 4.12.

We propose to modify equations as follows:

<u>Roskam original</u> <u>Modified</u>

for airframe

$$C_{dapsp} = \frac{F_{dapsp} \cdot F_{apsp} \cdot \left(AMP - N_e \cdot C_{e.m}\right)}{DP_{apsp} \cdot \left(U_{ann.bl} \cdot V_{bl}\right)} \qquad C_{dapsp} = \frac{F_{dapsp} \cdot C_{mat\_ap\_tot}}{DP_{ap}}$$

$C_{mat\_ap\_tot}$ - airframe spare parts cost of per nm (with applied cost burden)

for engines

$$C_{dengsp} = \frac{F_{dengsp} \cdot F_{engsp} \cdot N_e \cdot C_{e.m} \cdot ESPPF}{DP_{endsp} \cdot \left(U_{ann.bl} \cdot V_{bl}\right)} \qquad C_{dengsp} = \frac{F_{dengsp} \cdot C_{meng.tot}}{DP_{eng}}$$

$C_{mat\_ap\_tot}$ - engines spare parts cost of per nm (with applied cost burden)

This solves the problem (see Fig. 4.12).

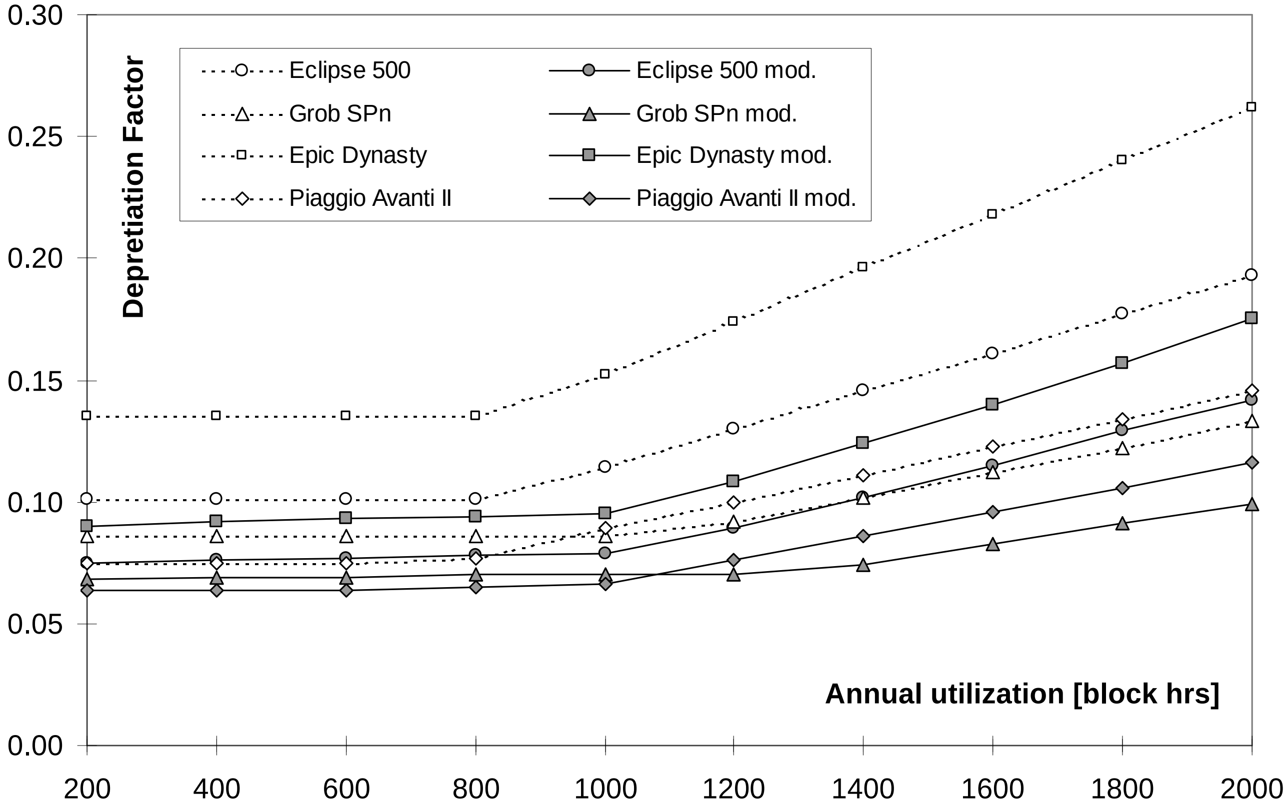


Fig.4. 12 Airplane depreciation factor vs utilization intensity

5 DATA FOR CALCUATIONS

5.1 DATA GROUPS AND SOURCES

For direct operating cost calculations many data are needed. It can be broken into three categories as below:

- Technical Data
  - number of seats (for pilots and passengers)
  - life time limits for: airframe, engines, propellers and avionics systems
  - time between overhaul (engines)
  - airplane and engines weights
  - aerodynamics characteristics
  - propulsion systems characteristics

- Economic Data
  - prices of: airplane, engines, propellers and avionics systems
  - fuel price
  - labour cost of crew and mechanics
  - costs of insurance and taxes
  - costs of navigation and landing fees

- Mission Data
  - block time
  - flight time
  - block fuel

The last group – mission data – could be a problem especially. There are two method of acquiring them. First based on published data, second requires detailed calculations. First method is much faster, however has several disadvantages. For example: “Business and Commercial Aviation” contains mission data for three defined missions at one payload condition (usually 4 pax. @200 lbs for turbine airplanes and 3 to 4 pax. @170 lbs for pistons). For medium (up to 9 pax.) and large (up to 19 pax.) size aircraft this is an important limitation. Maximum payload differs from published too much. The solution is a second method. In this case it is necessary to create airplane aerodynamics characteristic and propulsion system characteristics. Flight mechanics model is also needed. All these difficulties are offset by large potential of this method. It is possible to set: payload and fuel weights as well as flight profile (speed and altitude). This allows to examin dependance between DOC and particular flight parameter.

Figures 5.1 and 5.2 present two methods mentioned above.

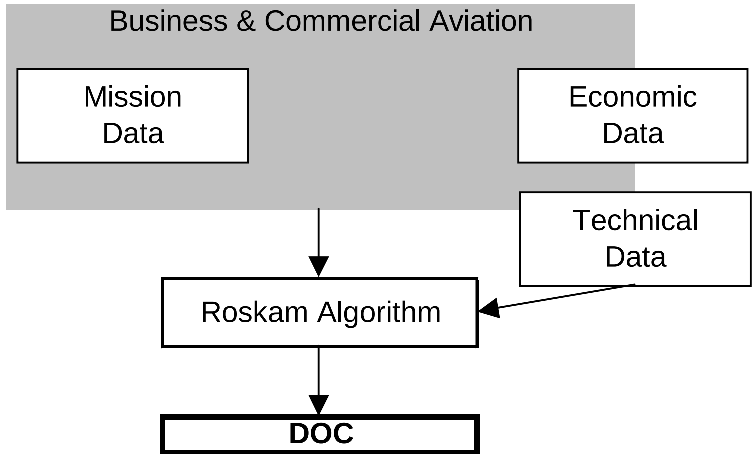


Fig.5. 1 DOC calculation based on published data

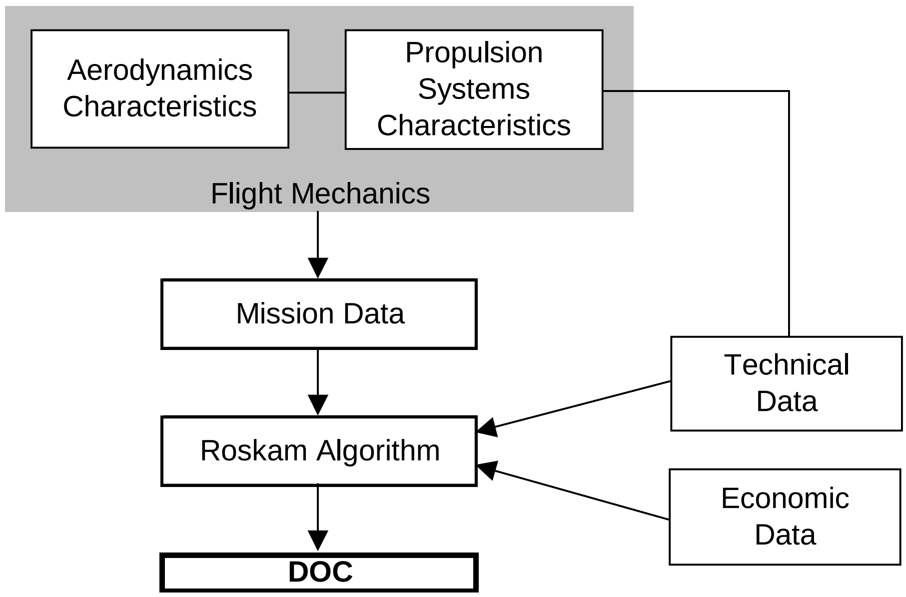


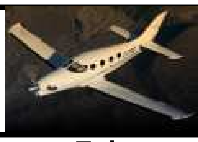
Fig.5. 2 DOC calculation using flight mechanics model

5.2 AIRCRAFT DATA

Detailed data for particular airplanes are shown in tables 5.1 to 5.4. In tables below, payload means both: passengers and pilots weight. This way is more flexible, it makes weight buildup easier, especially when number of pilots is changing.

EPATS AIRCRAFT REFERENCE LIST	**SINGLE-ENGINE PISTONS** 
Manufacturer	**Cirrus**
Model	**SR-22**
Price [Milions]	$ 0.371/0.470
Certification Year	2000?
Characteristic	
Seating	1+**3**
Dimensions Internal [m]	
Lenght	3.3
Width	1.24
Hight	1.27
Cabin Volume [m^3]	*4.081*
Cab. Vol.per Pax. Seat	*1.020*
Seat Pitch [m]	
Power	
Engine	Teledyne Continental IO-550-N
Price [€]	
Output [kW]	231
Weight	187
SFC	
TBO [h]	2000
Weights [kg]	
Max. TO	1542
Max. Payload	
Useful Load	531
Max. Fuel	301 (251 usable)
Performance	
Max. Cruise/Altitude [km/h /]	343 (2438m/75%p.)
Service Ceiling [m]	5334
Rate of Climb [m/min]	426
TO Distance to 15 m [m]	486
DOC/(pax*km)	
litre/(pax*km) - Cruise	0.044
Range	
Cruise Speed/Altitude [m] Range [km]/Payload	75% P/2438 1502/- 2167 (55% P) / -

Fig.5. 1 Single-engine pistons data

EPATS AIRCRAFT REFERENCE LIST	**SINGLE ENGINE TURBOPORPS**	
		
Manufacturer	**Epic**	**Pilatus**
Model	**Dynasty**	**PC-12**
Price [Milions]	$ 1.950	€ 2.24
Certification Year	2008	1994
Characteristic		
Seating	1+ **5**	2 + 6 / (**8**) 9
Dimensions Internal [m]		
Lenght	4.57	5.16
- Lavatory	*1.00*	*0.6*
- Seating Area	3.57	*4.56*
Width	1.4	1.53
Hight	1.49	1.47
Cabin Volume [m^3]	*7.487*	*10.358*
Cab. Vol.per Pax. Seat	***1.248***	*1.726 / (**1.295**) 1.151*
Seat Pitch [m]	***1.19***	*1.52 / (**1.14**) 0.91*
Power		
Engine	P&WC PT6-67A	P&WC PT6A-67B
Price [€]		
Output [kW]	895	895
Weight [kg]	230	234
SFC [kg/(kW*h)]	0.335	0.336
TBO [h]	3000	3500
Weights [kg]		
Max.Ramp	*3347.1*	4760.0
Max TO	3314.0	4740.0
Empty Weight Equiped[kg]	1816.0	2887.0 / 2661.0
Max. Zero Fuel		4100
Max. Payload [kg]	613	1123 / 1349
Max. (Usable) Fuel [kg]	856-1070	(1227)
Useful Load [kg]	*1531.1*	1873 / 2099
Performance		
Max. Cruise [kmh]	630	500
Altitude-Max. Cruise		FL250
Service Ceiling	FL310	FL300
Rate of Climb [m/min]		480
TO Distance 15 m (BFL) [m]	488	(917)
DOC/(pax*km)		
litre/(pax*km) - Block		
Range		
Cruise Speed/Altitude [m]	533 / -	- / FL242
Range [km]/Payload	2870 / 1+5	2583 /1+9 Hi Speed 2904 /1+9 Long R
Reserves	IFR	NBAA IFR

Tab.5.2 Single-engine turboprops data

EPATS AIRCRAFT REFERENCE LIST	**MULTI-ENGINE TURBOPROPS**	
		
Manufacturer	**Piaggio**	**BAE**
Model	**Avanti II**	**Jetstream 32EP**
Price [Milions]	€ 5.85	€ 4.9 ?
Certification Year	2006	1997
Characteristic		
Seating	2 + 6 / **8** / 9	2 + **19**
Dimensions Internal [m]		
Lenght	4.55	7.39
- Lavatory	*0.6*	*0.6*
- Seating Area	*3.95*	*6.79*
Width	1.85	1.85
Hight	1.75	1.8
Cabin Volume [m^3]	*11.569*	*19.327*
Cab. Vol.per Pax. Seat	*1.928 / **1.446** / 1.285*	***1.017***
Seat Pitch [m]	*1.32 / **0.99** / 0.79*	***0.68***
Power		
Engine	P&WC PT6A-66B	Garett TPE331-12
Price [€]		
Output [kW]	2 x 634	2 x 761
Weight [kg]	213 (v. 66)	182
SFC [kg/(kW*h)]	0.378 (v. 66)	0.333
TBO [h]	3000 (v. 66/A)	3600-**5000**-5400
Weights [kg]		
Max.Ramp	5511	*7433.6*
Max TO	5489	7360
Empty Weight Equiped[kg]	*3470.2*	*4512.4*
Max. Zero Fuel	4445	6736
Max. Payload [kg]	907	2223.6
Max. (Usable) Fuel [kg]	*1271.2*	1489
Useful Load [kg]	*2040.8*	*2921.2*
Performance		
Max. Cruise [kmh]	737	491
Altitude-Max. Cruise	FL280	
Service Ceiling	FL410	FL250
Rate of Climb [m/min]	899	
TO Distance 15 m (BFL) [m]	(1295)	1432
DOC/(pax*km)		
litre/(pax*km) - Block		
Range		
Cruise Speed/Altitude [m]	-/-	463 / -
Range [km]/Payload	1815 / 908 v.l 2791 / ?	915 / full pax. Load 1978 / 60% pax. load
Reserves	IFR	

Tab.5.3 Multi-engine turboprops data

EPATS AIRCRAFT REFERENCE LIST	**MULTI-ENGINE JETS**	
		
Manufacturer **Model**	**Eclipse** **500**	**Grob** **SPn**
Price [Milons]	$ 1.520 (€ 1.126)	€ 5.80
Certification Year	2007	2008 ?
Characteristic		
Seating	1+ **4** / 5	1+9 / 2**+8**
Dimensions Internal [m]		
Lenght	3.76	5.10
- Lavatory		1.04
-Seating Area		4.06
Width	1.42	1.52
Hight	1.27	1.64
Cabin Volume [m^3]	*5.325*	*11.347*
Cab. Vol.per Pax. Seat	*1.065 / 0.888*	*1.418*
Seat Pitch [m]	*0.85 / 0.85*	*1.015*
Power		
Engine	P&WC PW610F	Williams FJ44-3A
Price [€]		
Output [kN]	2 x 4.0	2 x 12.5
Weight [kg]		
SFC [kg/(kW*h)]		0.456
TBO [h]	3500	4000
Weights [kg]		
Max.Ramp	2737.2	*6363*
Max TO	2721.7	6300
Empty Weight Equiped	1648.0	*3727.4*
Max. Zero Fuel	2213.7	
Max. Payload [kg]		1130.0
Max. (Usable) Fuel [kg]	765	2000
2 Useful Load [kg]	1089.1	*2635.6*
Performance		
Max. Cruise [kmh]	685	754
Altitude-Max. Cruise		FL330
Service Ceiling	FL410	FL410
Rate of Climb [m/min]	1044	1320
TO Distance to 15 m (BFL) [m]	714	(914)
DOC/(pax*km)		
litre/(pax*km) - Cruise		
Range		
Cruise Speed/Altitude [m]		
Range [km]/Payload	1019 / 1+5x90.8 1426 / 1+4x90.8 1815 / 1+3x90.8	3334 / 1+6x90.8 3093 / 1+8x90.8
Reserves	NBAA IFR	IFR

Tab.5. 4 Single and multi-engine jets data

6 DIRECT OPERATING COST CALCULATION

6.1 ASSUMPTIONS

- €=1.35 $
- Fuel price: 4$/gal
- Crew cost: Appendix II (K=0)

Mission data calculation:

No.		Time	Fuel
1	Engine start and warm up	0	(1-0.997)*W_{TO}
2	Taxi	* $t_{gm} = 0.51 \cdot 10^{-6} \cdot W_{TO} + 0.125$	**t_{gm} min. at 20% T/P takeoff
3	Takeoff		1 min. at 100% T/P takeoff
4	Climb and acceleration	calculations: energy method – minimum time to climb trajectory: 1. acceleration from 1.15 V_{s_TO} to climb speed 2. climb and acceleration (to h_{cr}) 3. acceleration to V_{cr}	calculations: energy method – minimum time to climb trajectory:
5	Cruise	calculations; constant (average): cruise and altitude, at cruise T/P	calculations; constant (average): cruise and altitude, at cruise T/P
6	Descent and deceleration	calculations; constant descent rate=15.24 m/s Deceleration from V_{cr} to 1.15 V_{s_land}	calculations; at required T/P
7	Approach	As a part of descent – ATC maneuvers; for 0.5 h_{cr} and average speed during descent $t_{man} = 0.25 \cdot 10^{-6} \cdot W_{TO} + 0.0625$	calculations; at required T/P
8	Landing	*	***
9	Taxi back		**
10	Engine shut down	0	0

Tab.6 1 Mission phases

Ad.5 Cruise thrust (T) of power (P) equals:
- 80% of maximum takeoff value for all aircraft except Piaggio Avanti II
- 100% of maximum takeoff value for Piaggio Avanti II

The engine version prepared for Piaggio is derated. Normal cruise and climb are the same as maximum takeoff power (see certification sheets).

Calculations were made for 4 block distances selected on basis of Fig 6.1 (Ref[14]):
185, 370, 740 and 1482 km
(100, 200, 400 and 800 nm)

For each distance 3 flight levels were selected – the higher equals 90% of service ceiling. Exceptions:
- Cirrus SR-22 : the higher flight level: FL100
- Jetstream 32 EP : with 19 passengers and available fuel is too heavy to reach 90% of its maximum FL250. At FL200 cruise speed is below maximum range speed. So in this case FLs 50, 100, 150 were selected.

Flight distance equals 110% of great circle distance (block distance).

Load is defined as follows:
- 1 pilot for normal category aircraft, 2 for commuters; each at 91.8 kg (200 lbs)
- number of passengers, each at 91.8 kg (200 lbs); see tables 5.1 to 5.4 (bolded)
- fuel up to maximum ramp weight or maximum fuel weight, whichever occurs first.

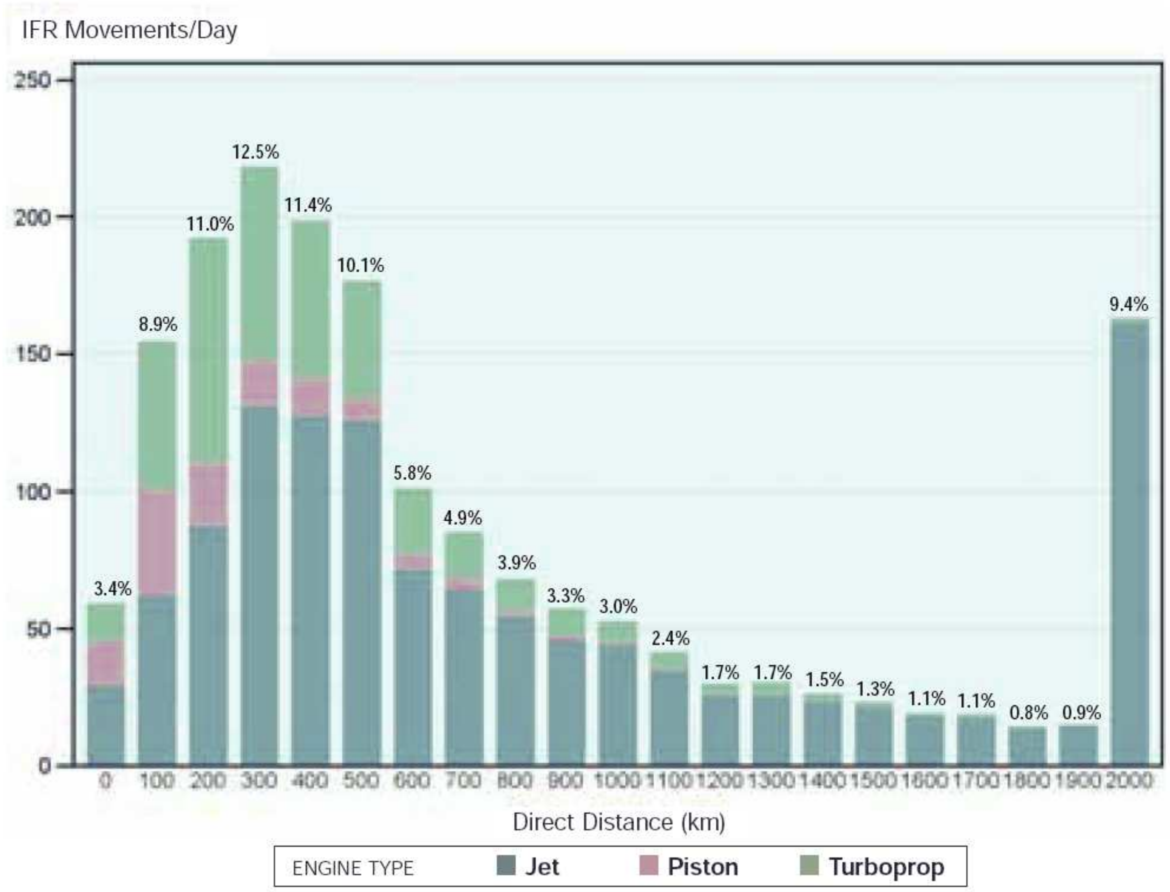


Fig.6. 1 Number of business IFR operations per day

Airframe life time:

- o 20 000 hours for all constructions, except Grob SPn
- o 27 000 hours for Grob

Engine and Propeller life time:

- o (2+1)*TBO [hrs]

6.2 MODEL VALIDATION

Notes:
For maximum range fuel consumption calculation:
- payload and fuel are as defined (publications)
- flight distance equals great circle distance (block distance)
- ATC maneuvering are removed.

For maximum speed calculation:
- take off weight is reduced
- reduced number of passengers

For NBAA IFR reserves calculation:
- flight distance equals great circle distance of 100 nm
- load as defined in paragraph 6.1
- ATC maneuvering are removed
- taxi is removed
- takeoff and landing are removed
- fuel weight to fulfill NBAA IFR requiremants.

Cirrus SR-22	**Data***	**Calc.**	**Error [%]**
Vmax ; 2438 m ; 100%P	342.0	335.0	**-2.0**
Wfuel (Rmax) 1502 km (1+3?)x200lb	206.8	195.6	**-5.4**
EPIC DYNASTY	**Data***	**Calc.**	**Error [%]**
Vmax	629.7	605.0	**-3.9**
Wfuel (Rmax) 2870 km (612 kg) economy cruise	768.4	681.2	**-11.3**
PILATUS PC-12	**Data***	**Calc.**	**Error [%]**
Vmax	500.0	490.0	**-2.0**
Wfuel (Rmax) ; (1+9)@200? Lb			
2563 km (high speed)	1031.1	959.2	**-7.0**
2904 km (V.econo)	1031.1	972.2	**-5.7**
PIAGGIO AVANTI II	**Data***	**Calc.**	**Error [%]**
Vmax ; FL280	737.0	670.0	**-9.1**
Wfuel (Rmax) ; 2791 (1+4?)x200lb	1060.8	1035.2	**-2.4**
Jetstream 32EP	**Data***	**Calc.**	**Error [%]**
Vmax ; FL100?, 100%? P	490.8	485.0	**-1.2**
Norm oper. speed ; FL100?, 80%? P	463.0	435.0	**-5.7**
Wfuel (Rmax); FL100?, 80% P			
915 km (100% payload, FL100)	478.9	514.5	**7.4**
1978 km (60% payload, FL100)	1270.3	1045.5	**-17.7**
ECLIPSE 500	**Data***	**Calc.**	**Error [%]**
Vmax	685.0	680.0	**-0.7**
Wfuel (Rmax) 1426 km (1+4)x200lb	444.3	486.5	**9.5**
GROB SPn	**Data***	**Calc.**	**Error [%]**
Vmax ; 10 000 m	750.0	750.0	**0.0**
Ma	0.7	0.7	**0.0**
Wfuel (Rmax) 3093 km (1+8)x200lb	1458.1	1642.1	**12.6**

*We assume that maximum range flight requires all usable fuel minus reserves.

Tab.6 2 Results validation

6.3 RESULTS

6.3.1 Missions Results Review

Results of calculations for 600 annual block hours (as a current utilization level) are presented on Figures 6.2 to 6.5. In general block speed increases, while DOC and SFC decreases with distance. Moreover SFC decreses with flight altitude. However we can see a few irregularities. Especially for short distances and higher altitudes, SFC increases and DOC decreases. The reason is the airplane spend more time climbing to cruise flight level which consumes a lot of fuel. In addition speed during climb is lower than at cruise so block speed decreases and this fact influences DOC. For some conditions airplane has not enough distance to accelerate to cruise speed: for example Grob SPn: 185km at Fl300.
That interesting Piaggio Avanti II has higher SFC at FL369 than at FL300 even at longest distance. DOC also is higher. The explanation could be: it has realy low climb rate at such high altitudes, so time to climb and fuel to climb are high. Moreover cruise speed in this condition is far away from impressive maximum.

Reasuming, there is no single particular flight condition which can be named the best. One minimizes operating cost, the other fuel consumption. Another maximizes block speed. For purpose of aircraft demand calculation (WP2), block speed to operating cost ratio is selected as a measure of merit. Table 6.3 shows conditions for maximizing this ratio for particular airplanes.

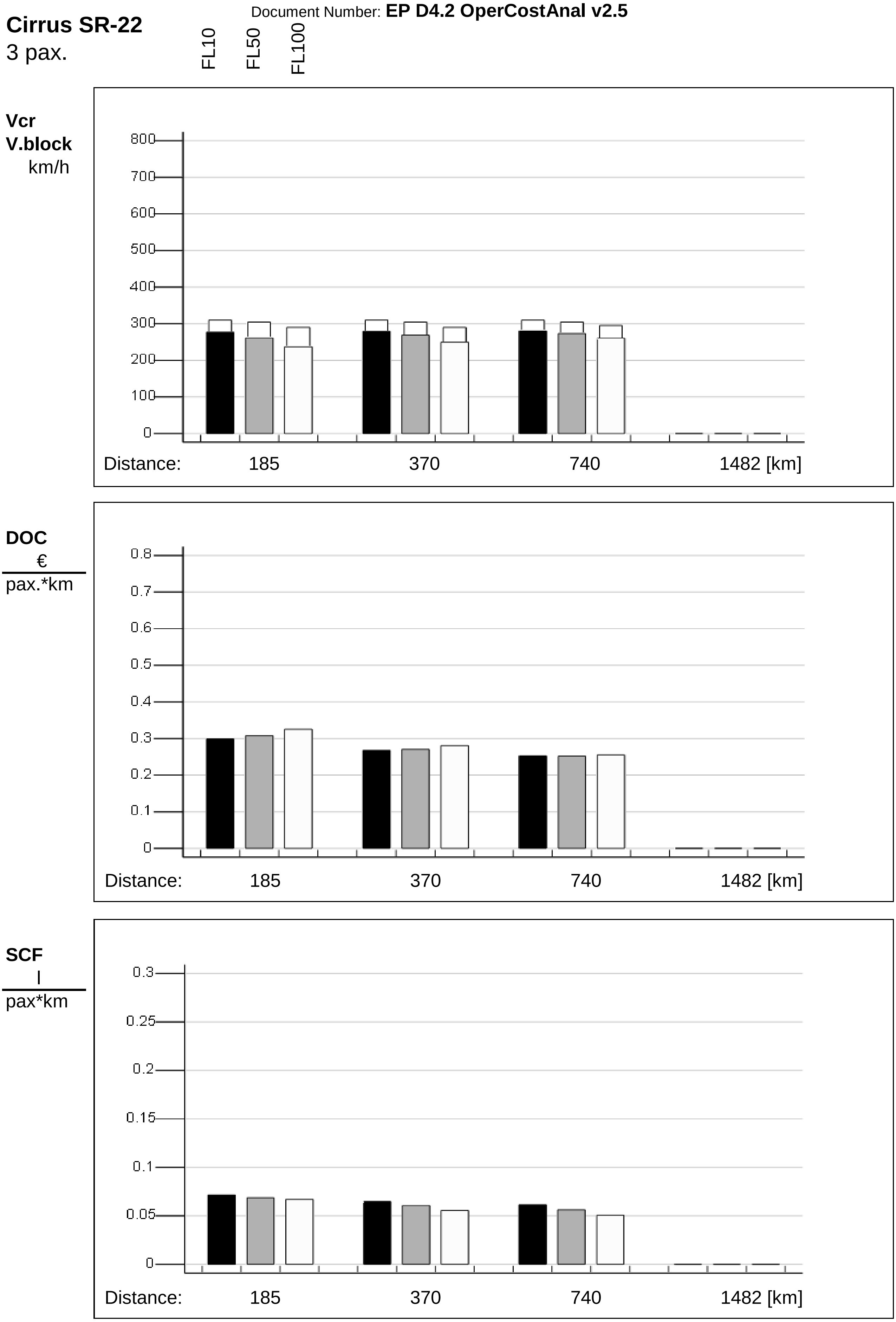


Fig.6. 2 Cirrus SR-22 results (600 block hours per year)

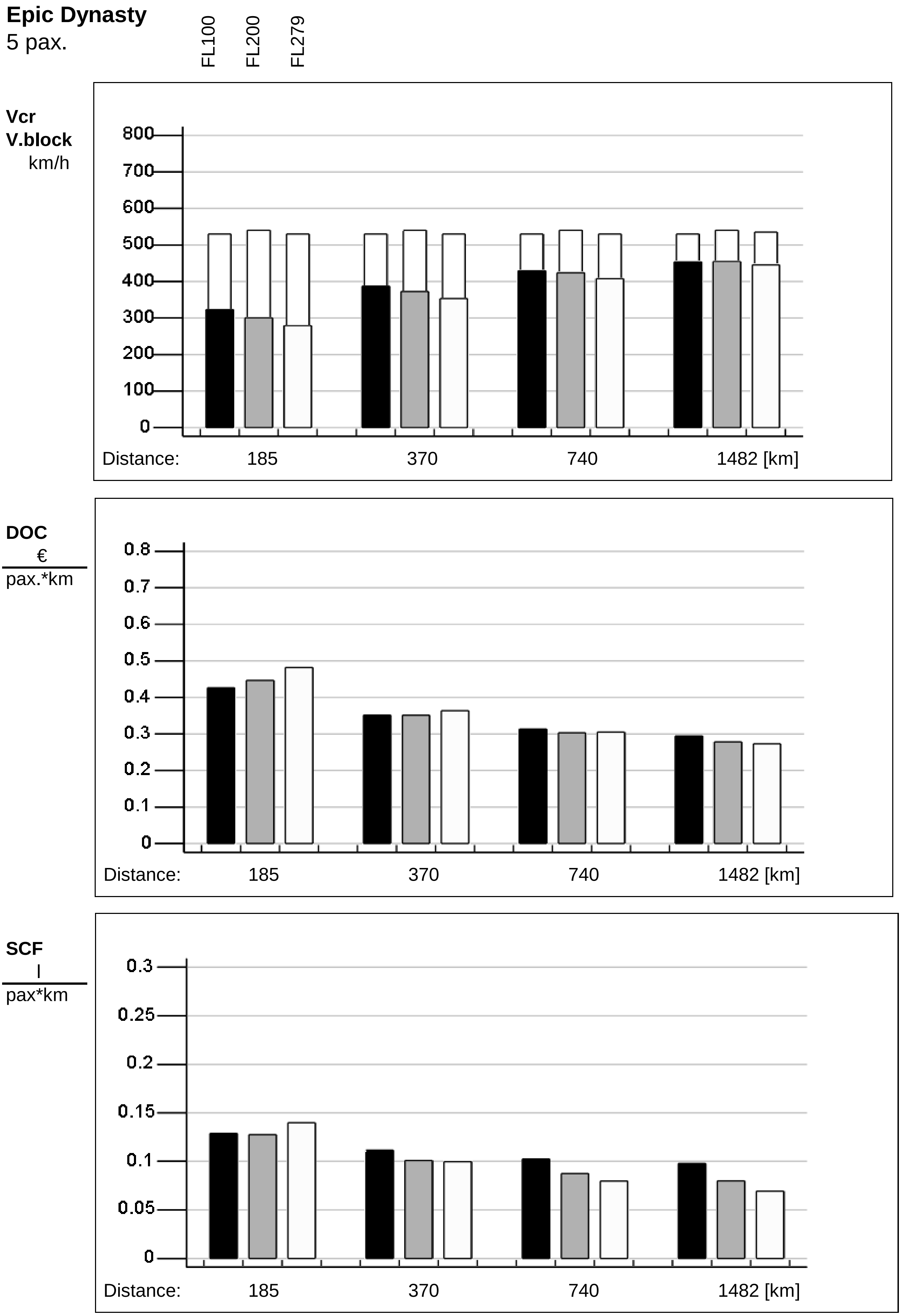


Fig.6. 3 Epic Dynasty results (600 block hours per year)

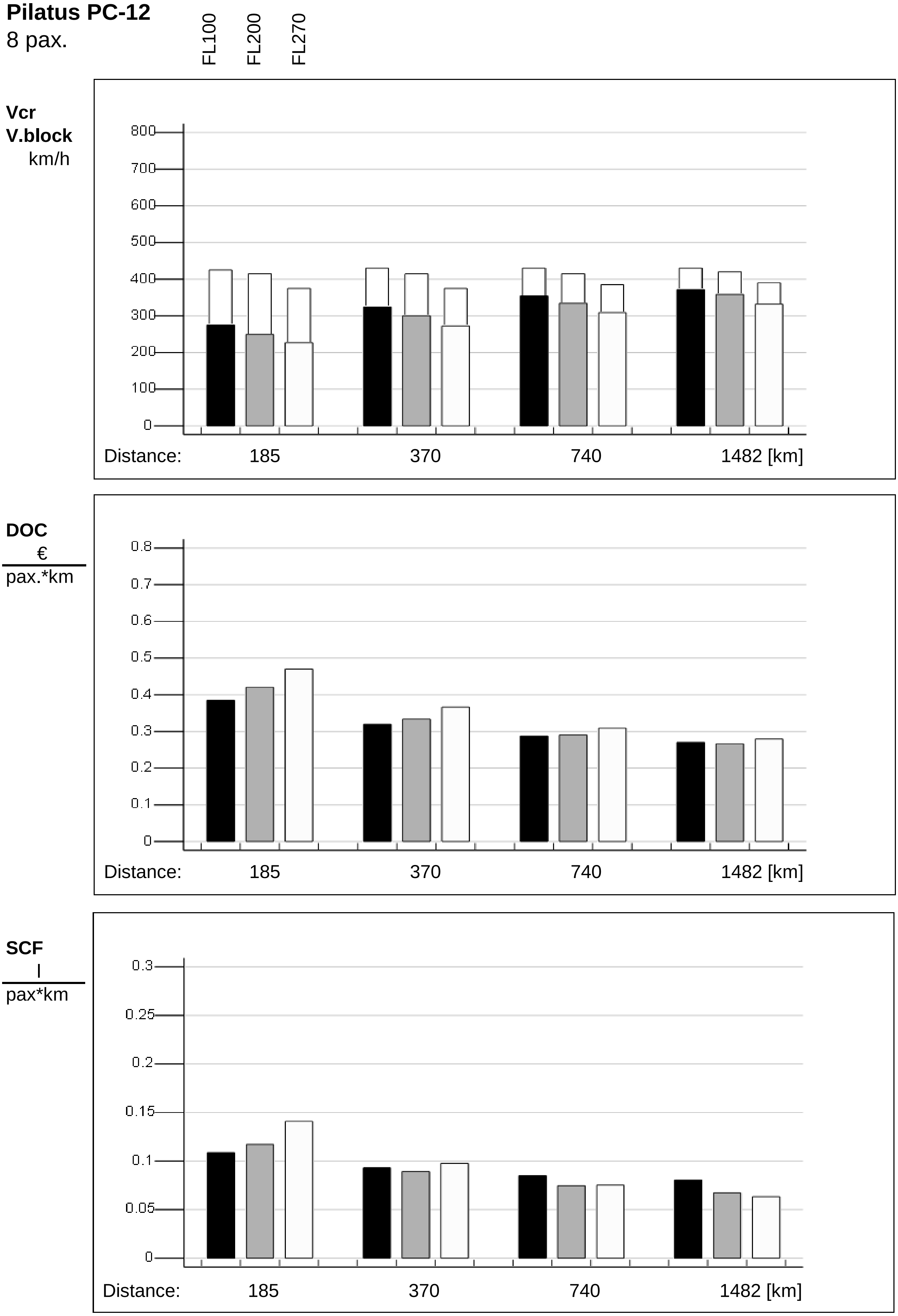


Fig.6. 4 Pilatus PC-12 results (600 block hours per year)

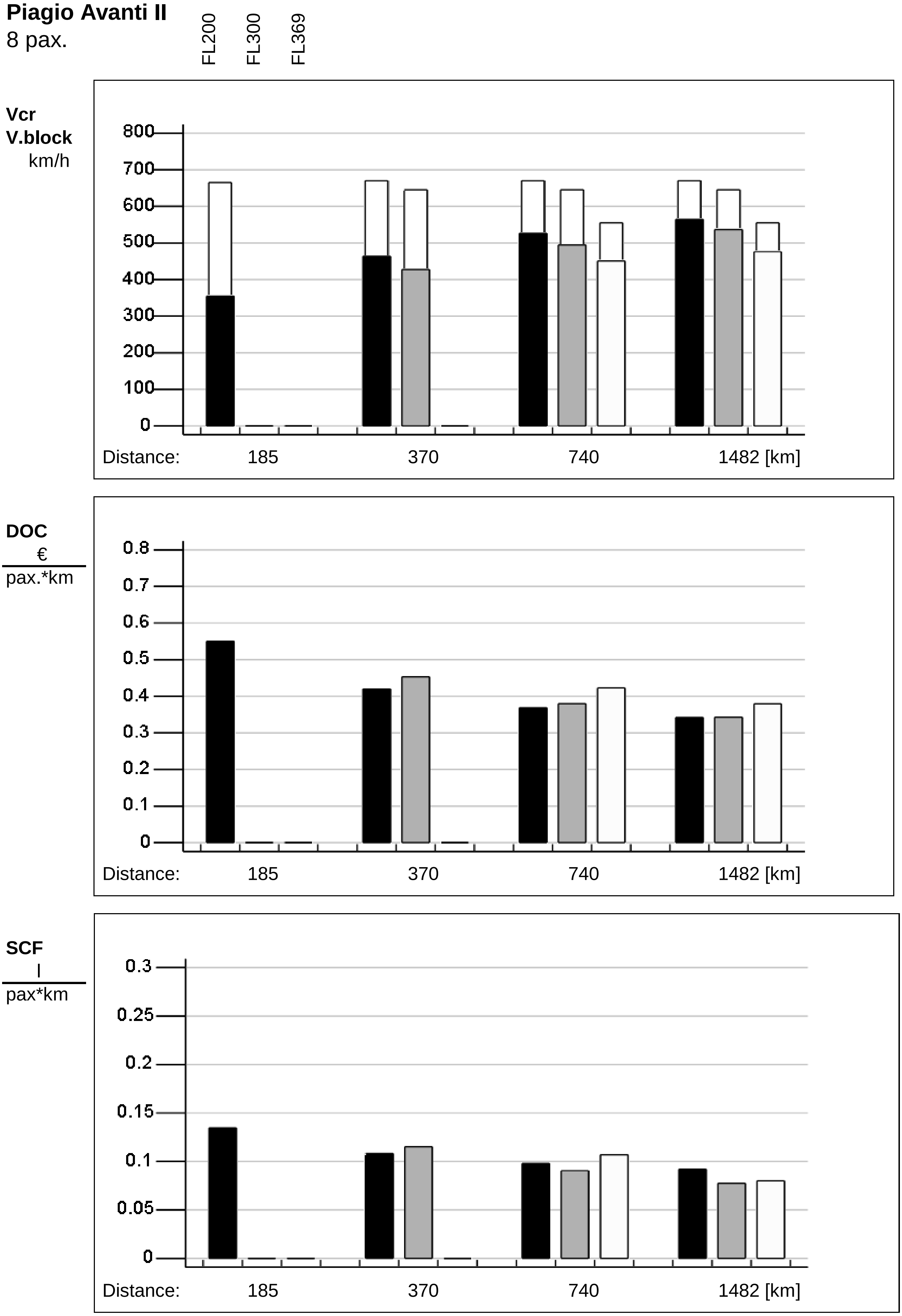


Fig.6. 5 Piaggio Avanti II results (600 block hours per year)

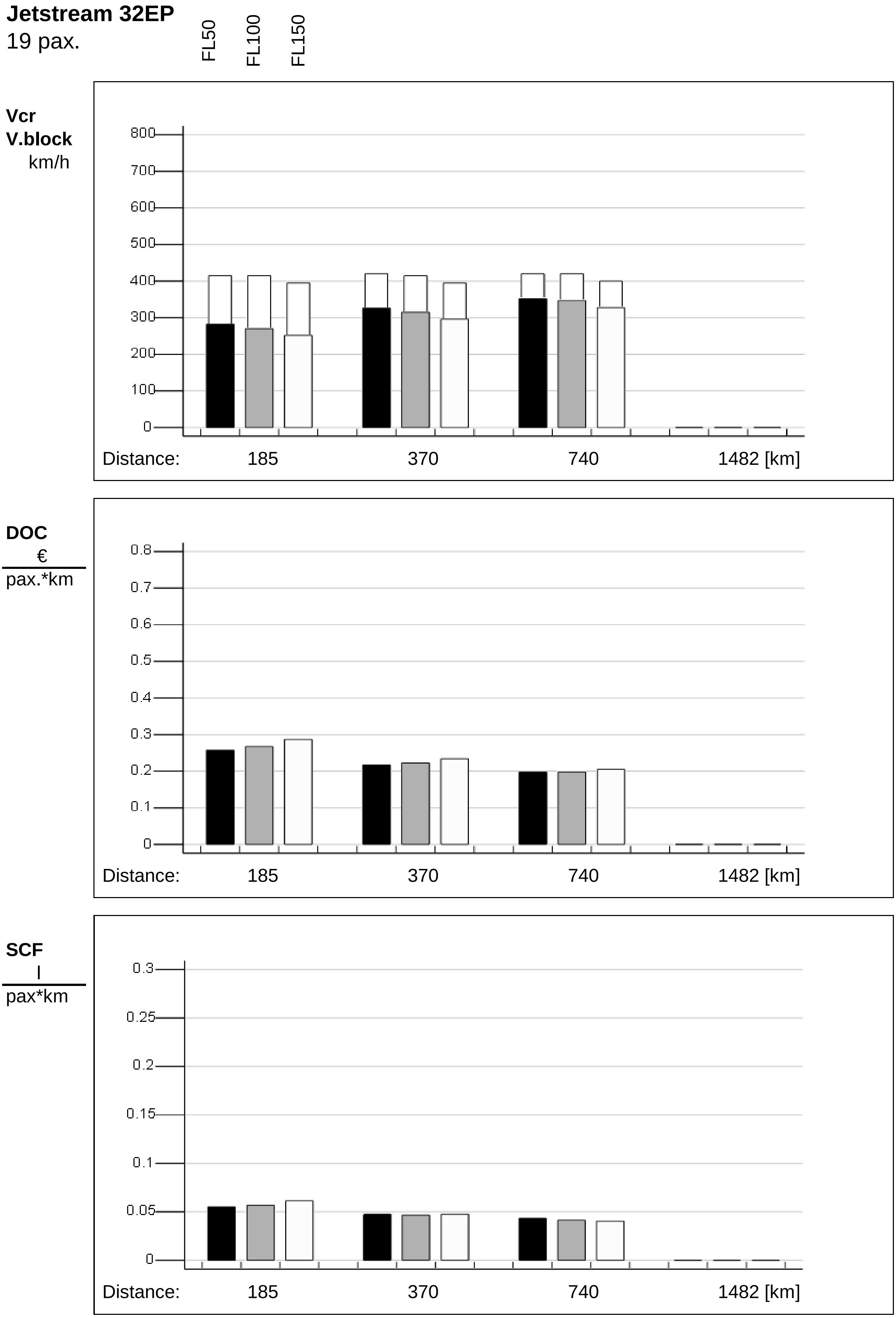


Fig.6. 6 Jetstream 32EP results (600 block hours per year)

Eclipse 500
4 pax.

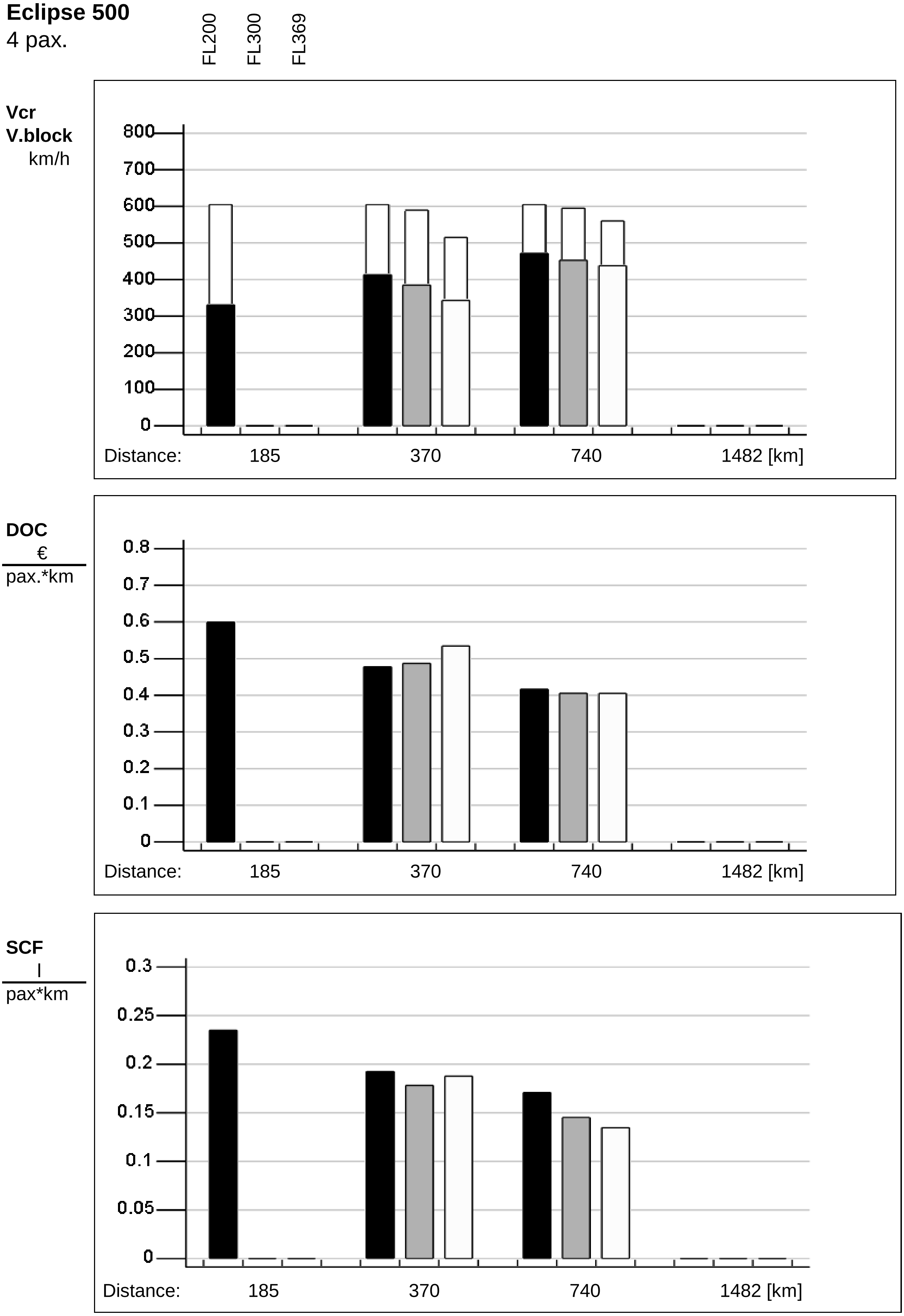
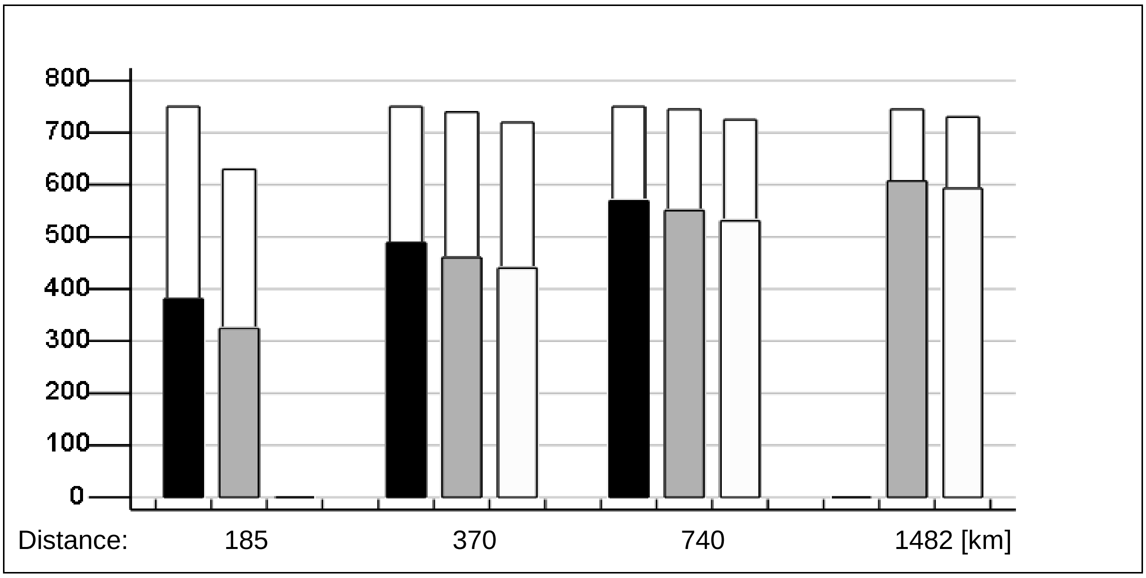


Fig.6. 7 Eclipse 500 results (600 block hours per year)

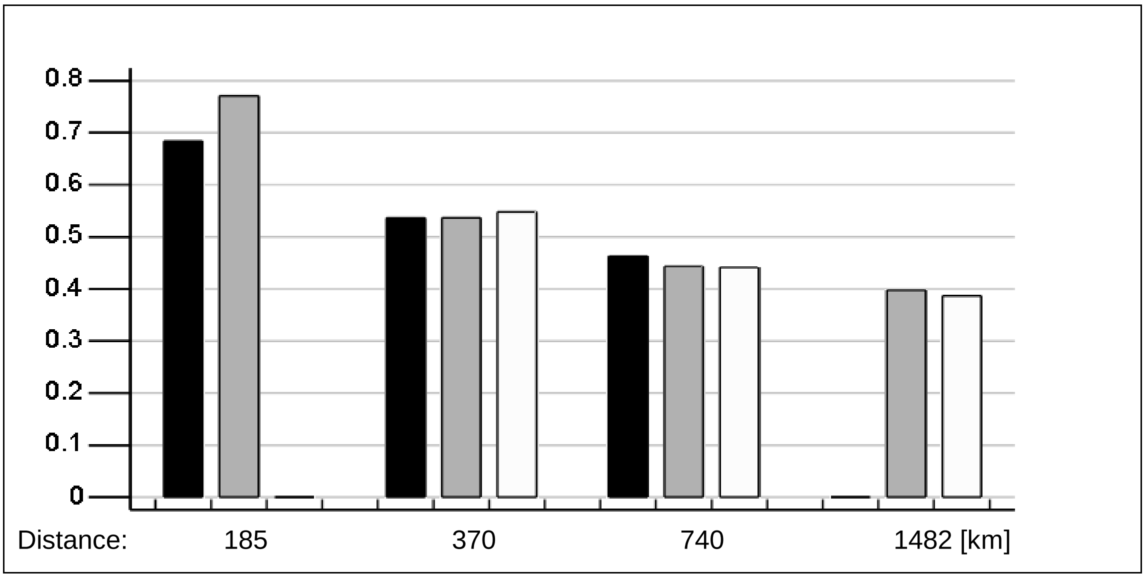
Grob SPn
8 pax.

FL200 FL300 FL369

Vcr
V.block
km/h



DOC
€ / pax.*km



SCF
l / pax*km

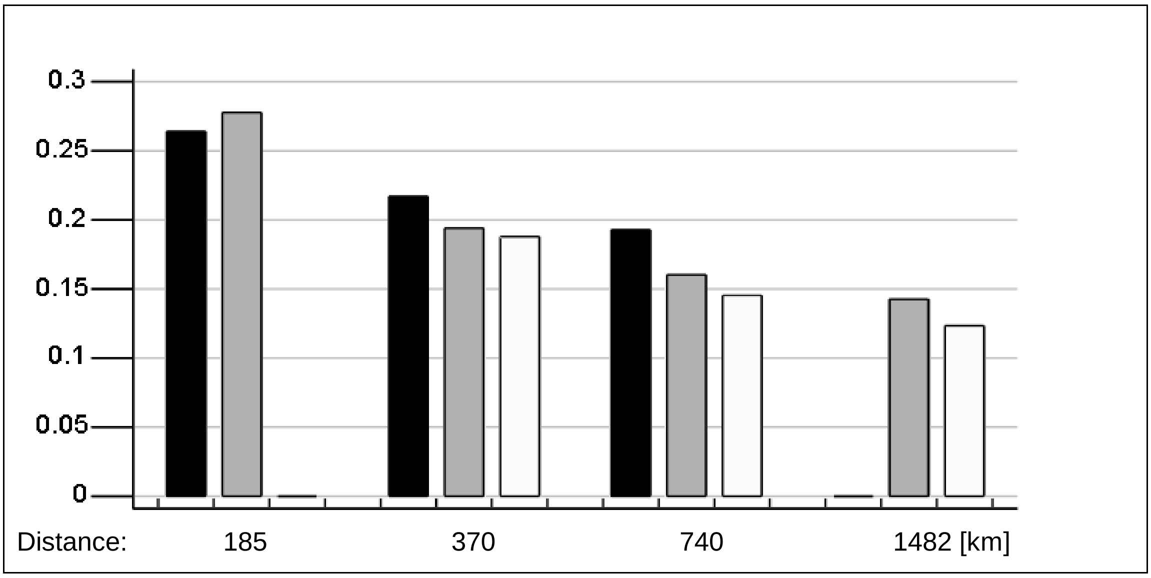


Fig.6. 8 Grob SPn Results (600 block hours per year)

6.3.2 Missions Results Summary

For particular airplanes, cruise conditions for maximizing V.block to DOC ratio are selected, see table 6.3.

Distance	185	370	740	1482
Cirrus SR-22	**FL10** FL50 FL100	**FL10** FL50 FL100	**FL10** FL50 FL100	
Distance [km]	185	370	740	1482
Epic Dynasty	**FL100** FL200 FL279	**FL100** FL200 FL279	FL100 **FL200** FL279	FL100 **FL200** FL279
Distance	185	370	740	1482
Pilatus PC-12	**FL100** FL200 FL270	**FL100** FL200 FL270	**FL100** FL200 FL270	**FL100** FL200 FL270
Distance [km]	185	370	740	1482
Piaggio Avanti II	**FL200** FL300 FL369	**FL200** FL300 FL369	**FL200** FL300 FL369	**FL200** FL300 FL369
Distance	185	370	740	1482
Jetstream 32EP	**FL50** FL100 FL150	**FL50** FL100 FL150	**FL50** FL100 FL150	
Distance [km]	185	370	740	1482
Eclipse 500	**FL200** FL300 FL369	**FL200** FL300 FL369	**FL200** FL300 FL369	
Distance [km]	185	370	740	1482
Grob SPn	**FL200** FL300 FL369	**FL200** FL300 FL369	FL200 **FL300** FL369	FL200 FL300 **FL369**

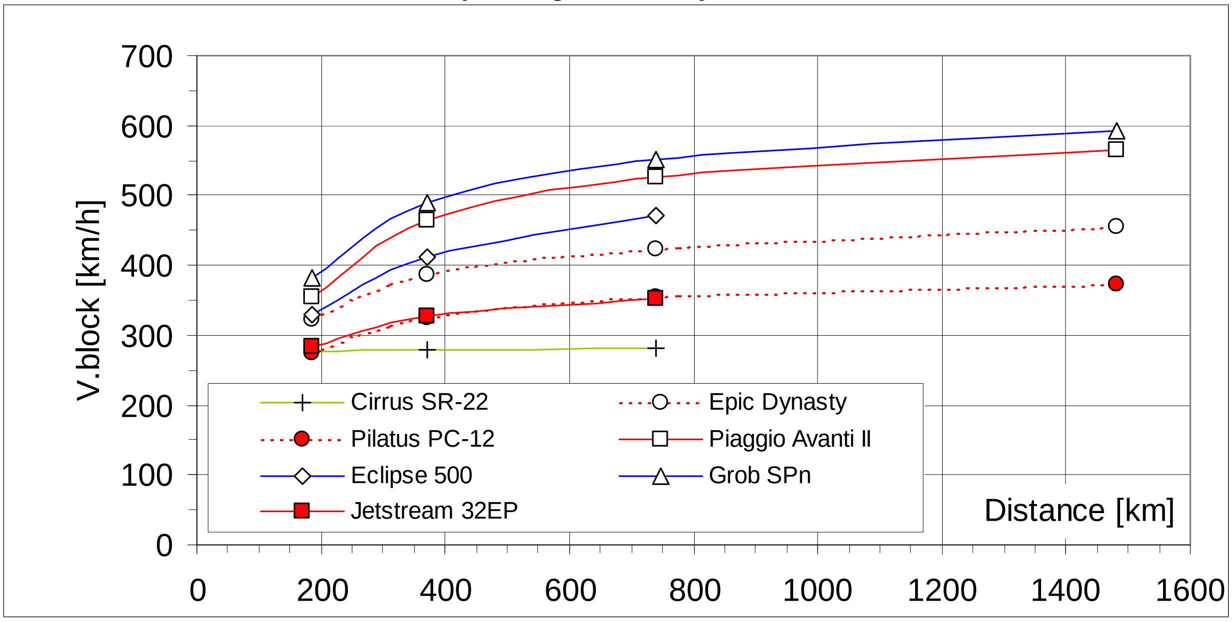
Tab.6 3 Flight level for maximum V.block to DOC ratio (for 600 annual block hours)

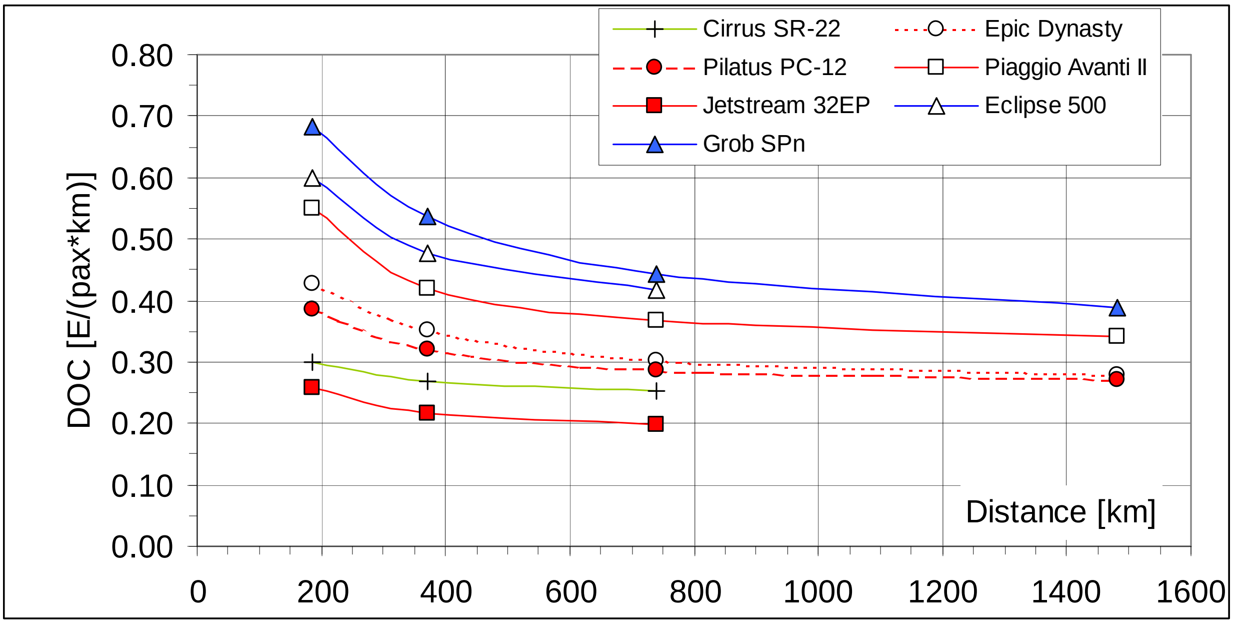
Now it is possible to show dependance of V.block, DOC, SFC and V.block/DOC on distance. Comparison of different class aircraft is very interesting: figures 6.10 to 6.13.

Figures 6.14 to 6.17 compare DOC fraction of all aircraft for particular distances.

Figures 6.17 to 6.24 present DOC changes with annual utilization level, for particular distances.

Figures 6.25 to 6.31 show how DOC fractions change with block distance for particular airplanes (for 600 annual block hours).





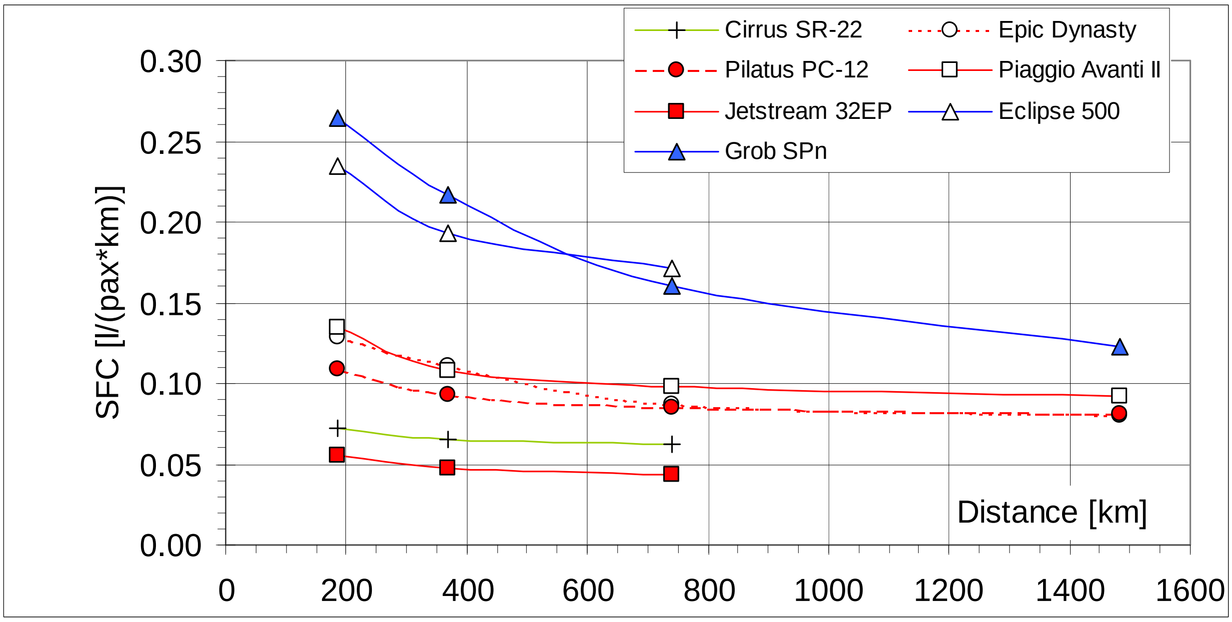


Fig.6. 9 Fig.6. 10 Fig.6. 11 Results summary (for 600 annual block hours)

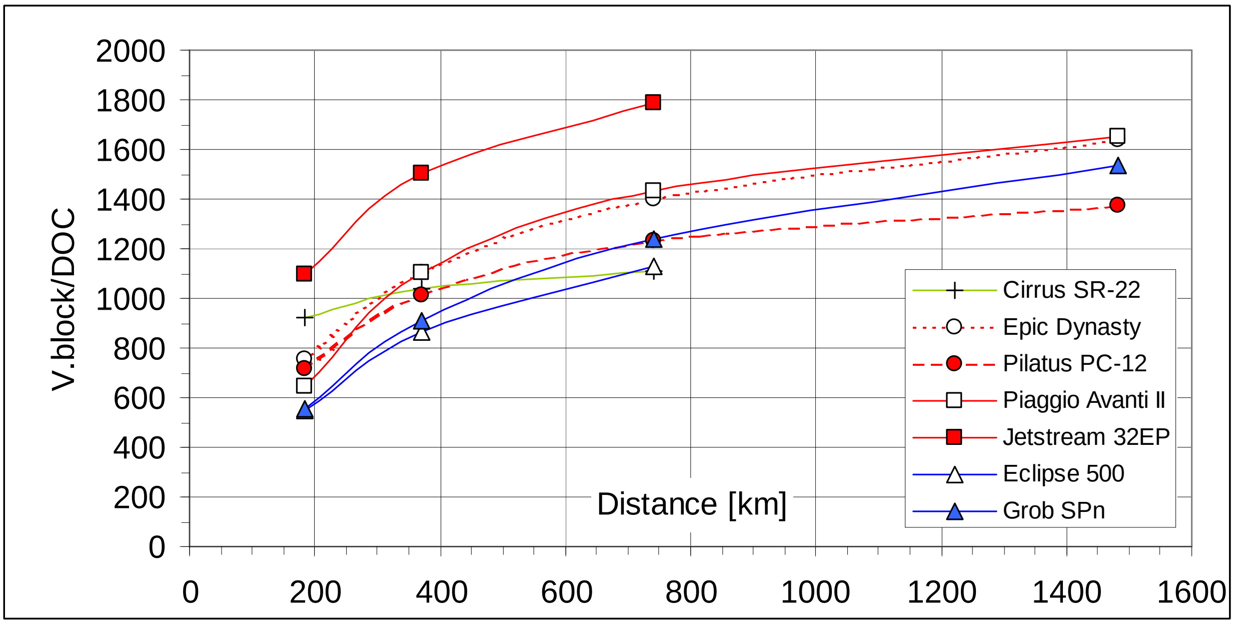


Fig.6. 12 V.block to DOC ratio (for 600 annual block hours)

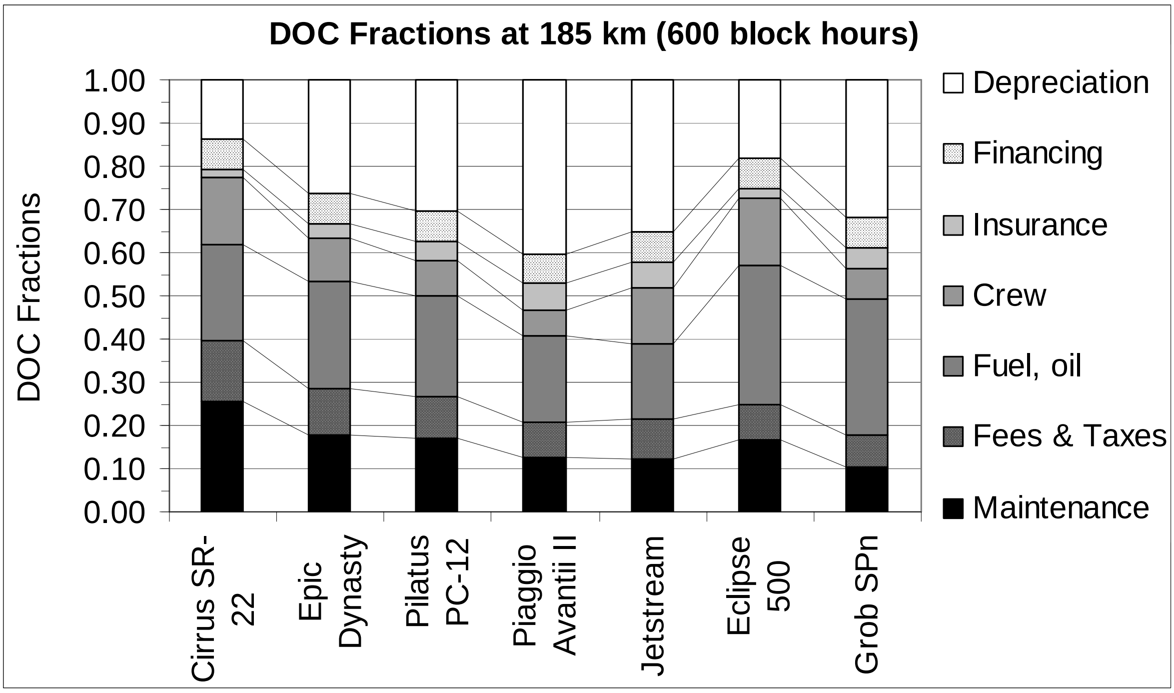


Fig.6. 13 DOC fractions for all aircraft at 185 km and 600 annual block hours

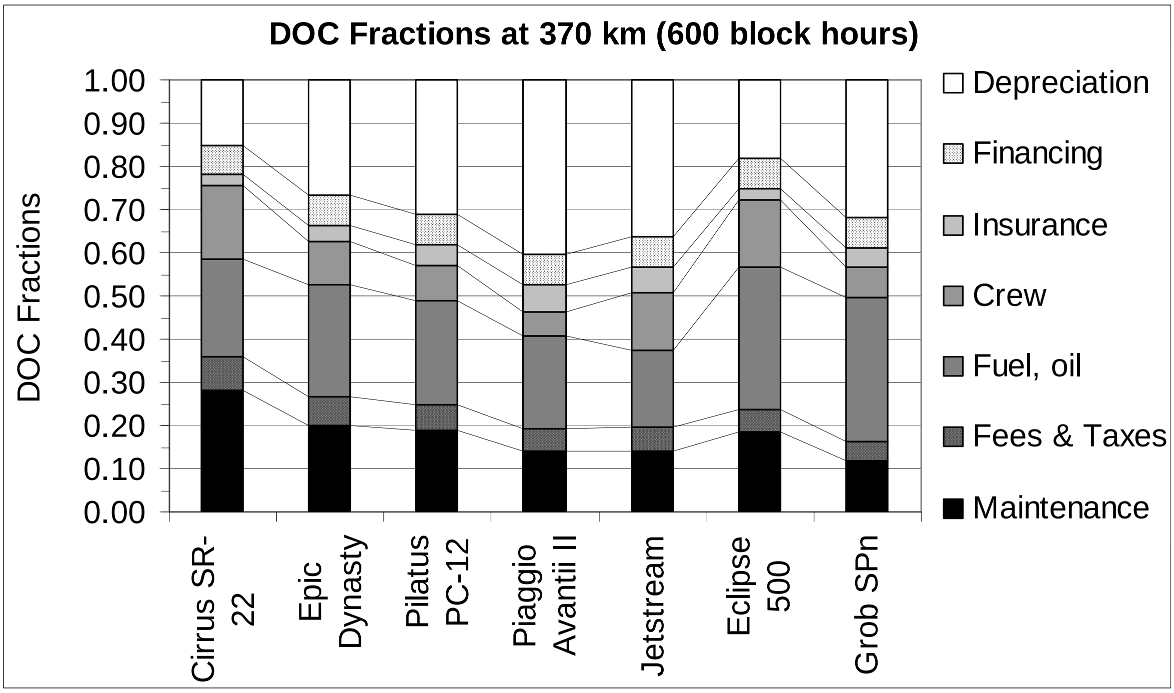


Fig.6. 14 DOC fractions for all aircraft at 370 km and 600 annual block hours

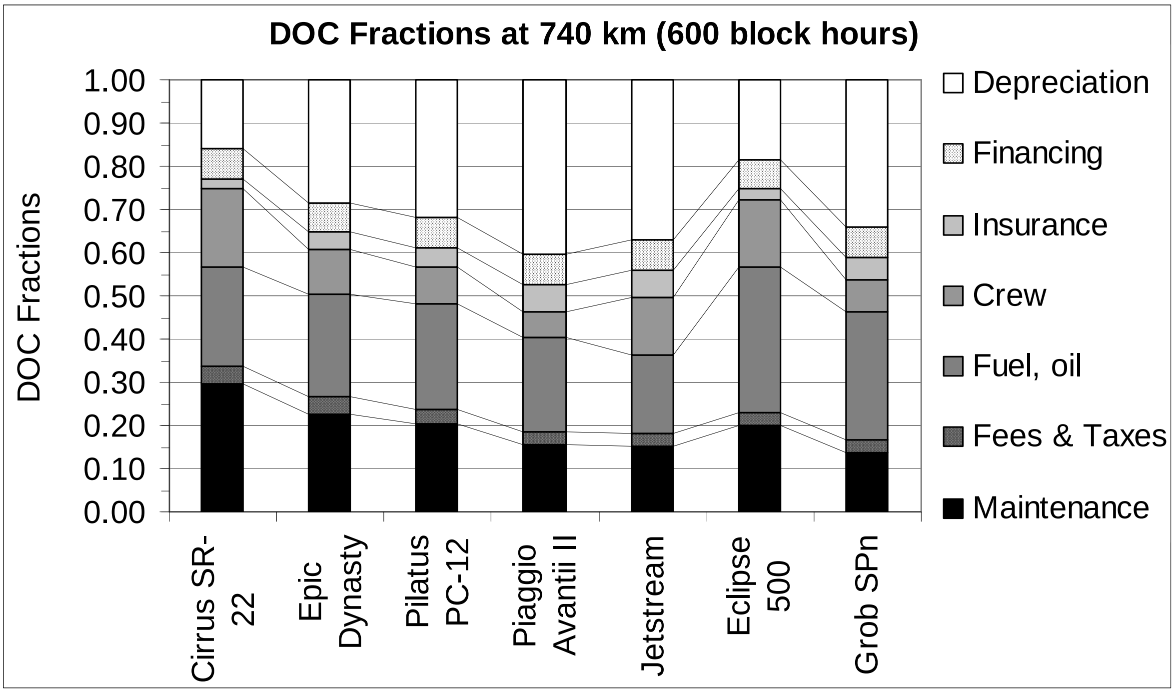


Fig.6. 15 DOC fractions for all aircraft at 740 km and 600 annual block hours

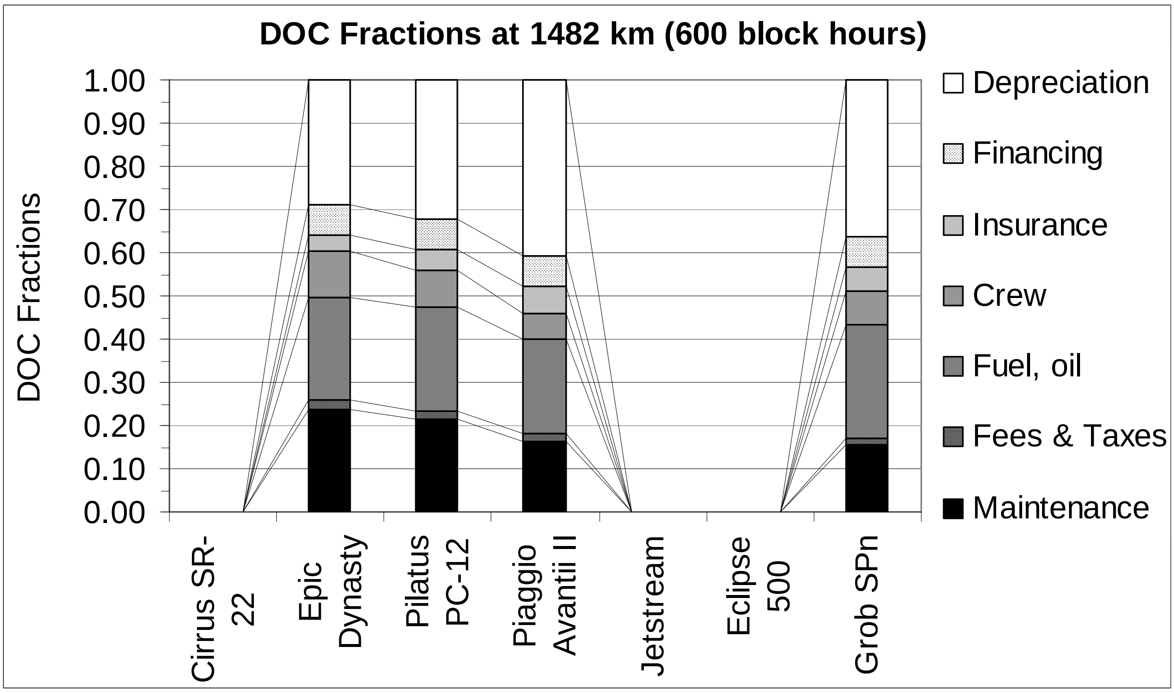


Fig.6. 16 DOC fractions for all aircraft at 1482 km and 600 annual block hours

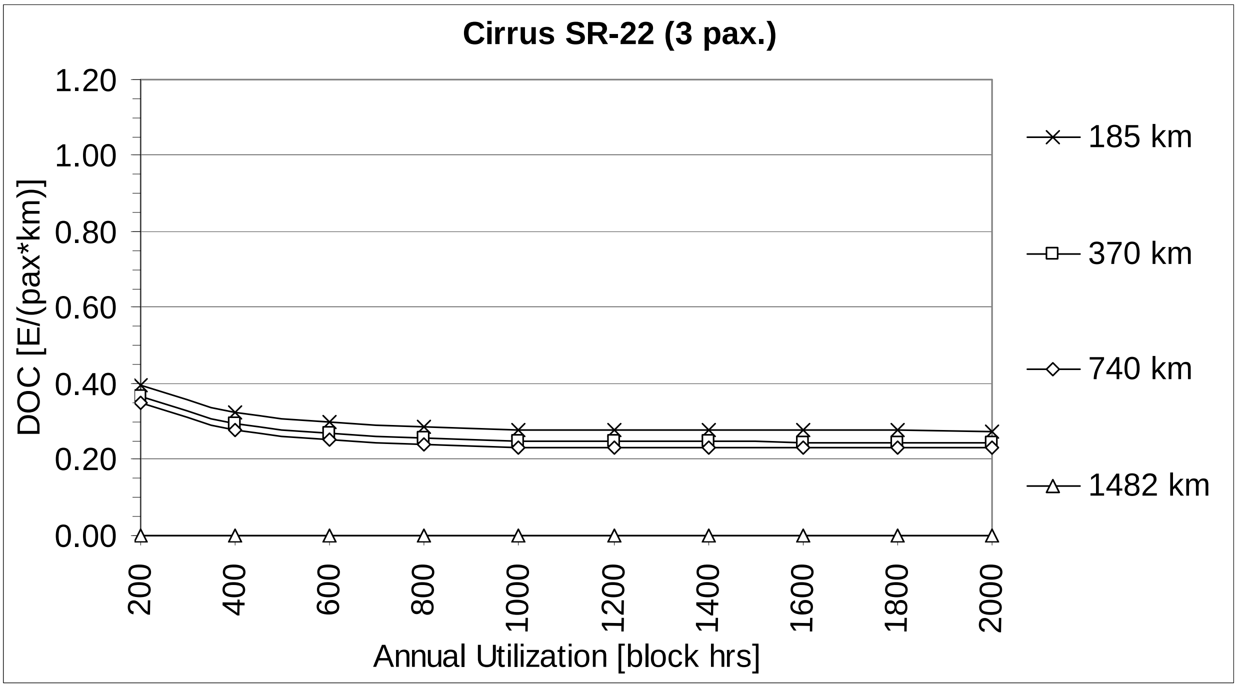


Fig.6. 17 DOC of Cirrus SR-22 as a function of annual utilization level

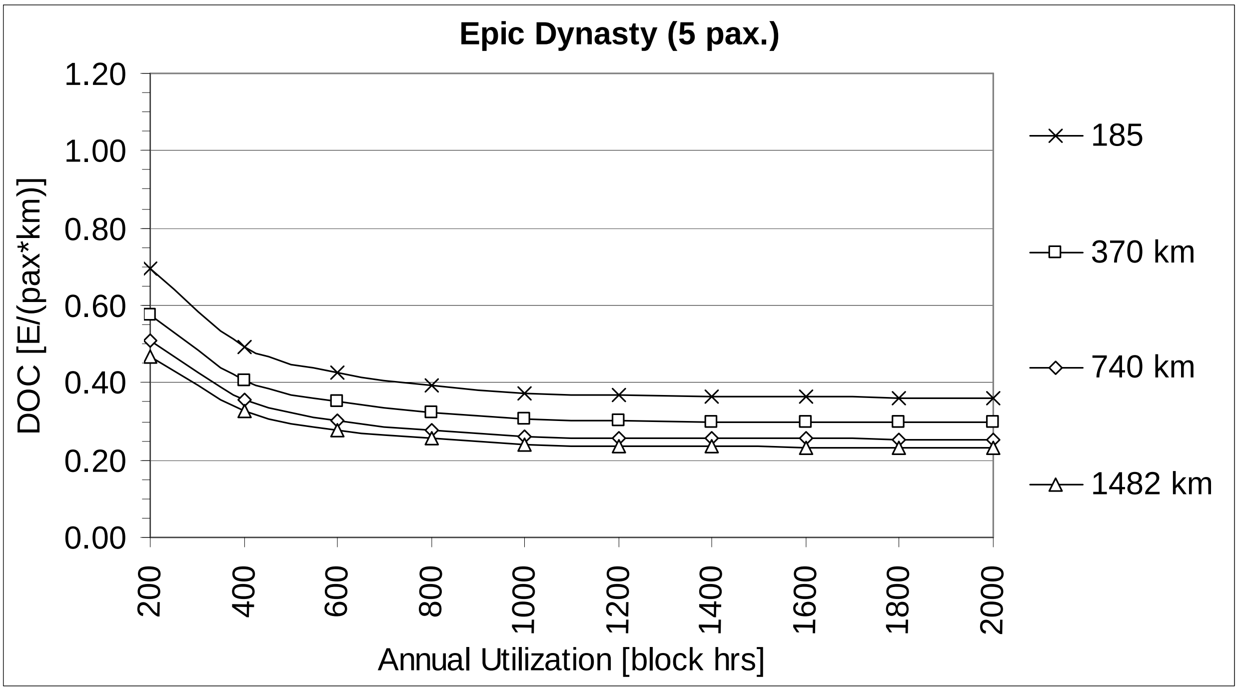


Fig.6. 18 DOC of Epic Dynasty as a function of annual utilization level

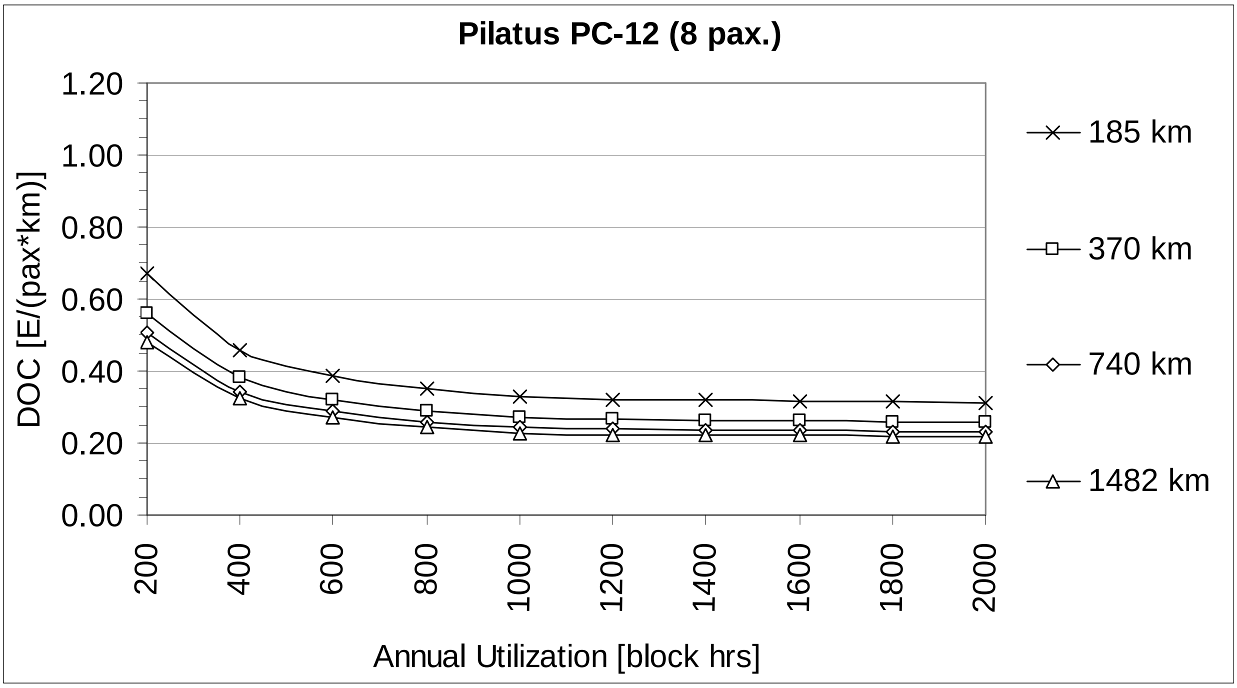


Fig.6. 19 DOC of Pilatus PC-12 as a function of annual utilization level

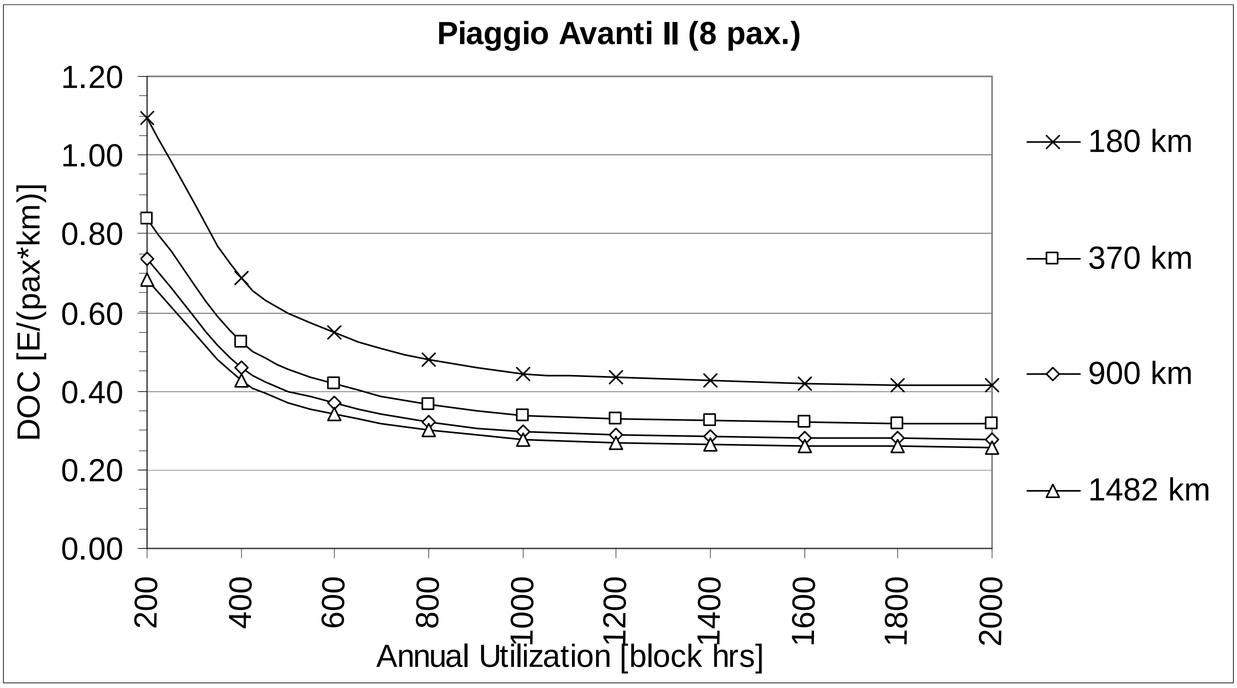


Fig.6. 20 DOC of Piaggio Avanti II as a function of annual utilization level

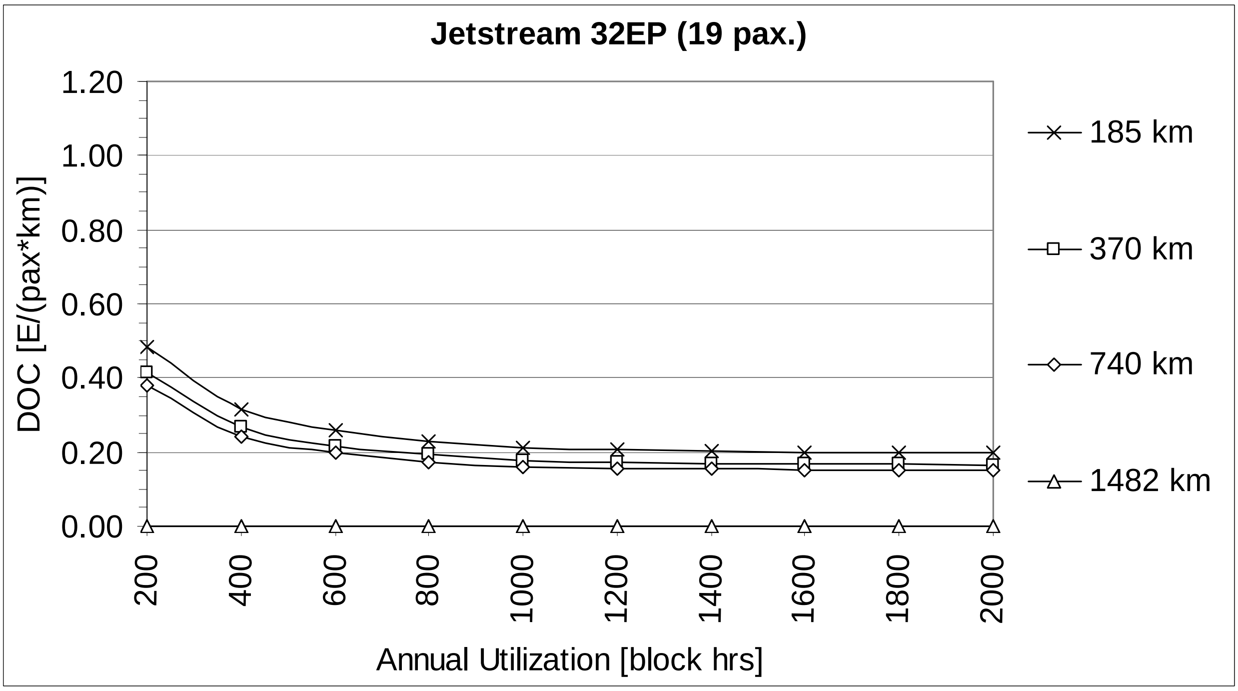


Fig.6. 21 DOC of Jetstream 32EP as a function of annual utilization level

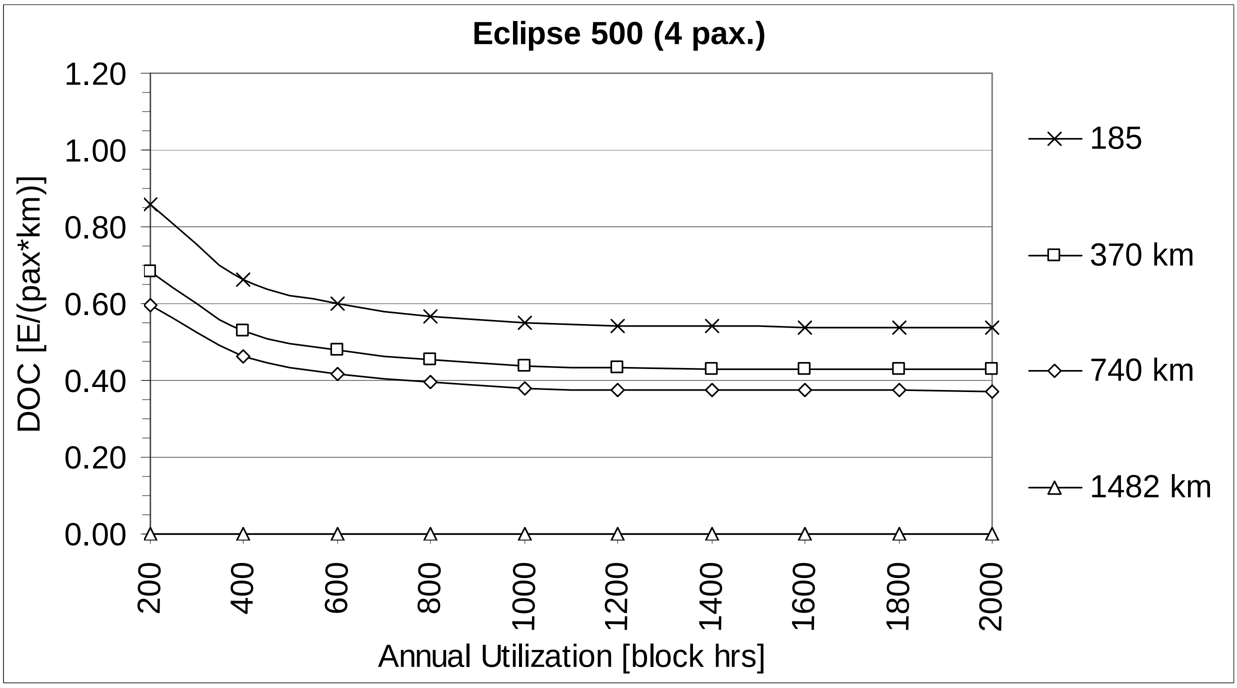


Fig.6. 22 DOC of Eclipse 500 as a function of annual utilization level

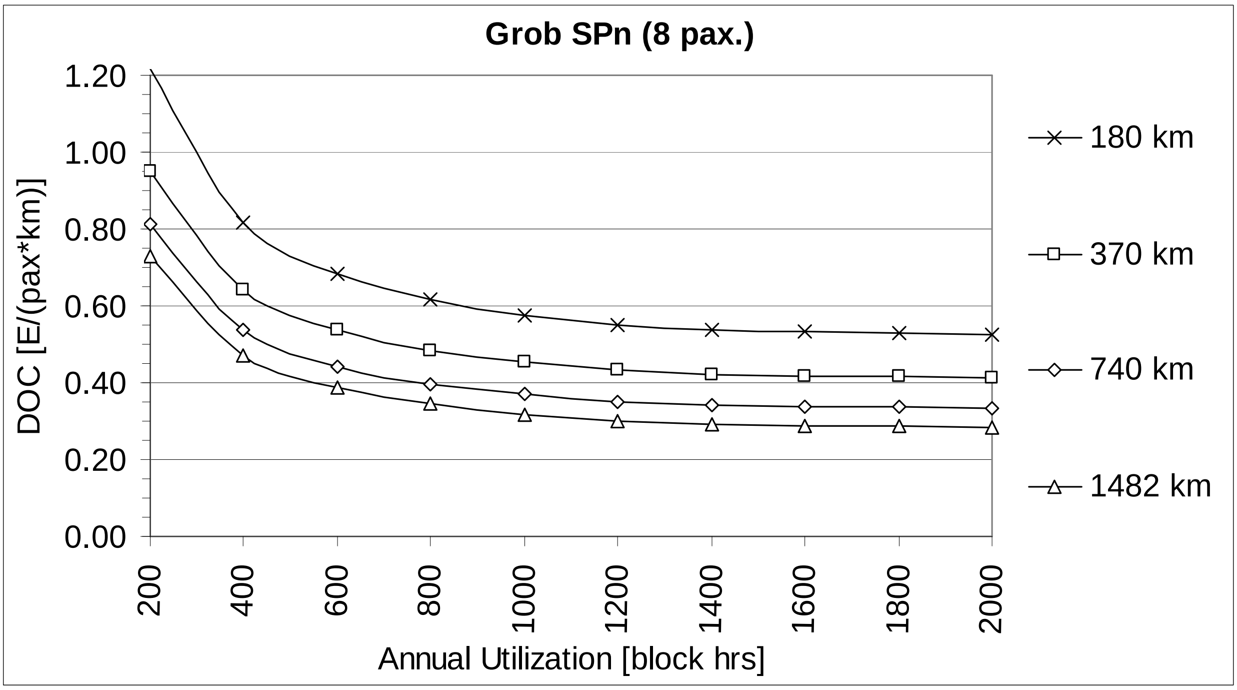


Fig.6. 23 DOC of Grob SPn as a function of annual utilization level

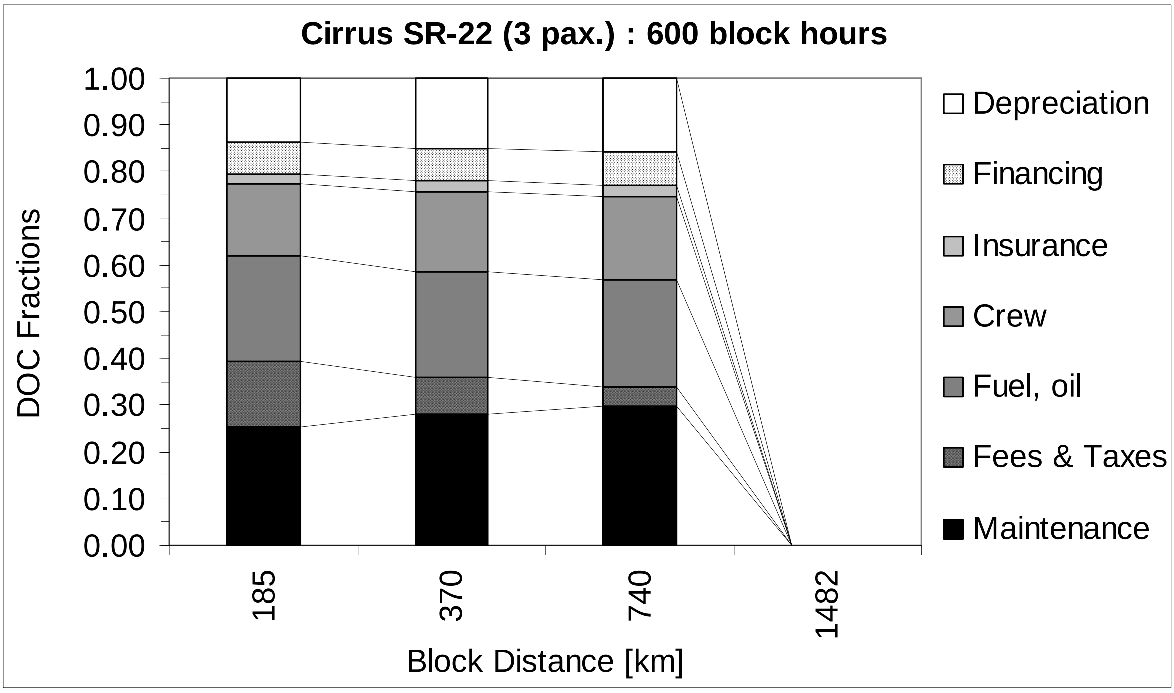


Fig.6. 24 DOC fractions changes with distance for Cirrus SR-22

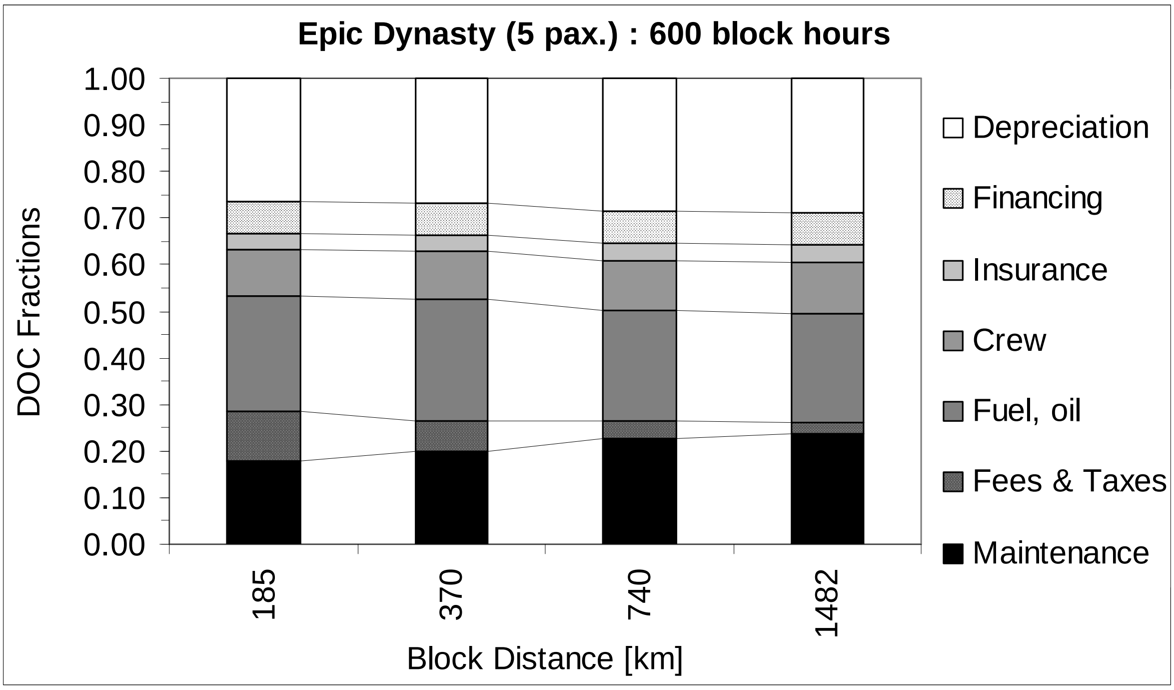


Fig.6. 25 DOC fractions changes with distance for Epic Dynasty

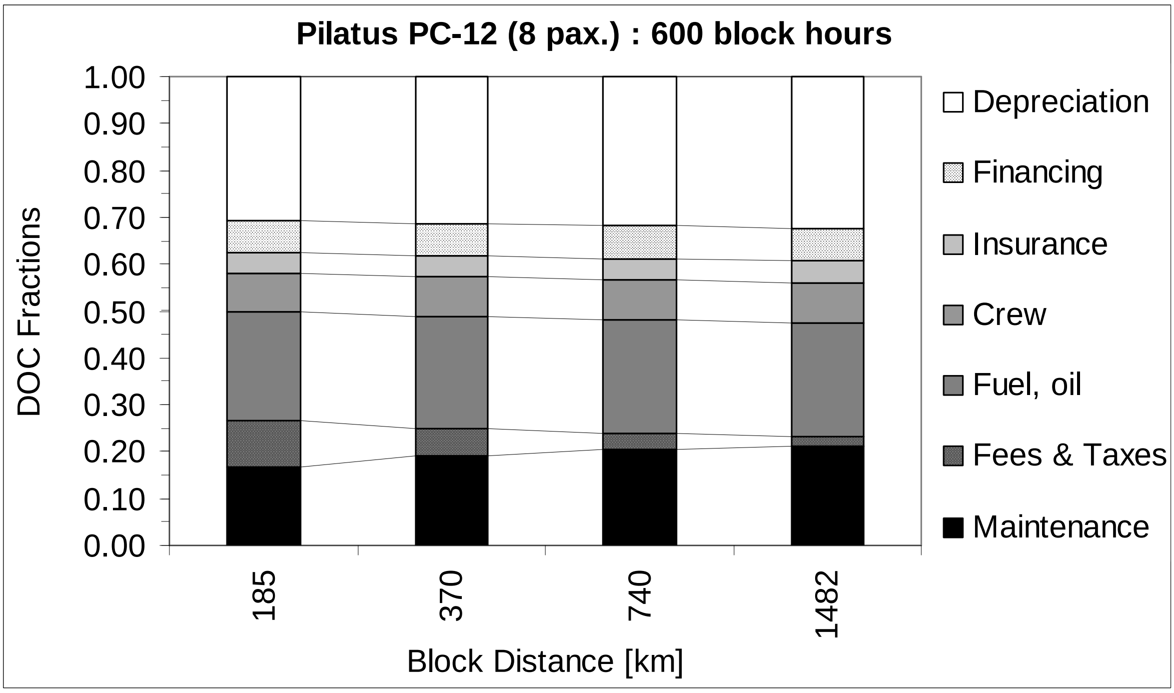


Fig.6. 26 DOC fractions changes with distance for Pilatus PC-12

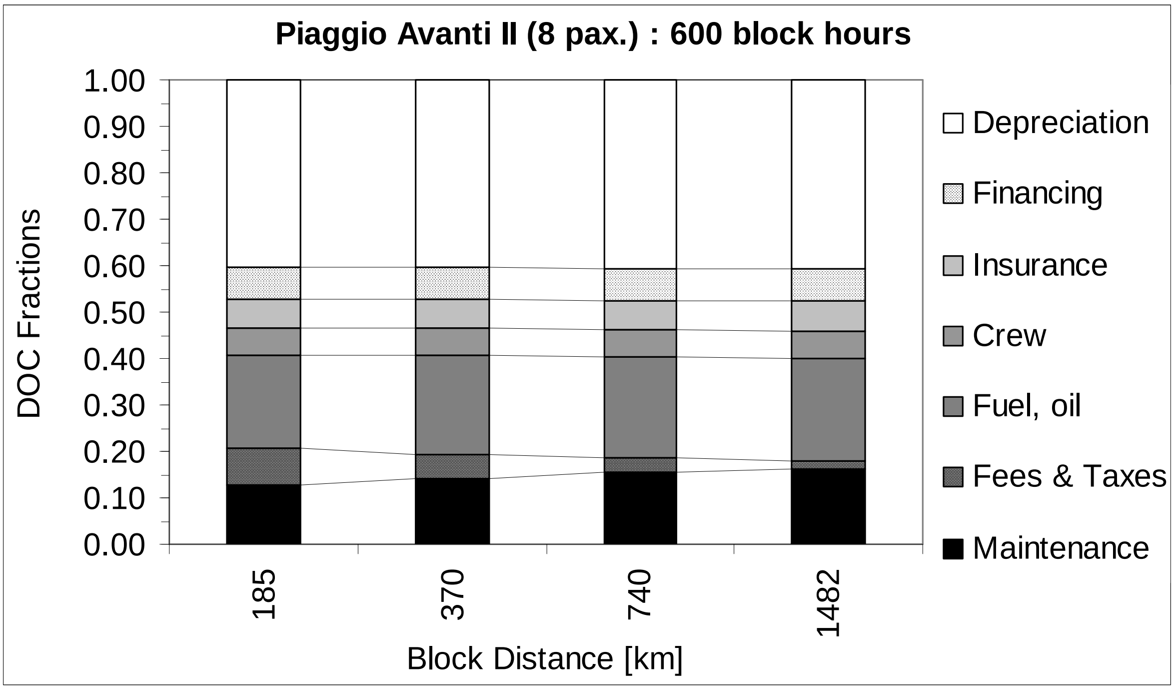


Fig.6. 27 DOC fractions changes with distance for Piaggio Avanti II

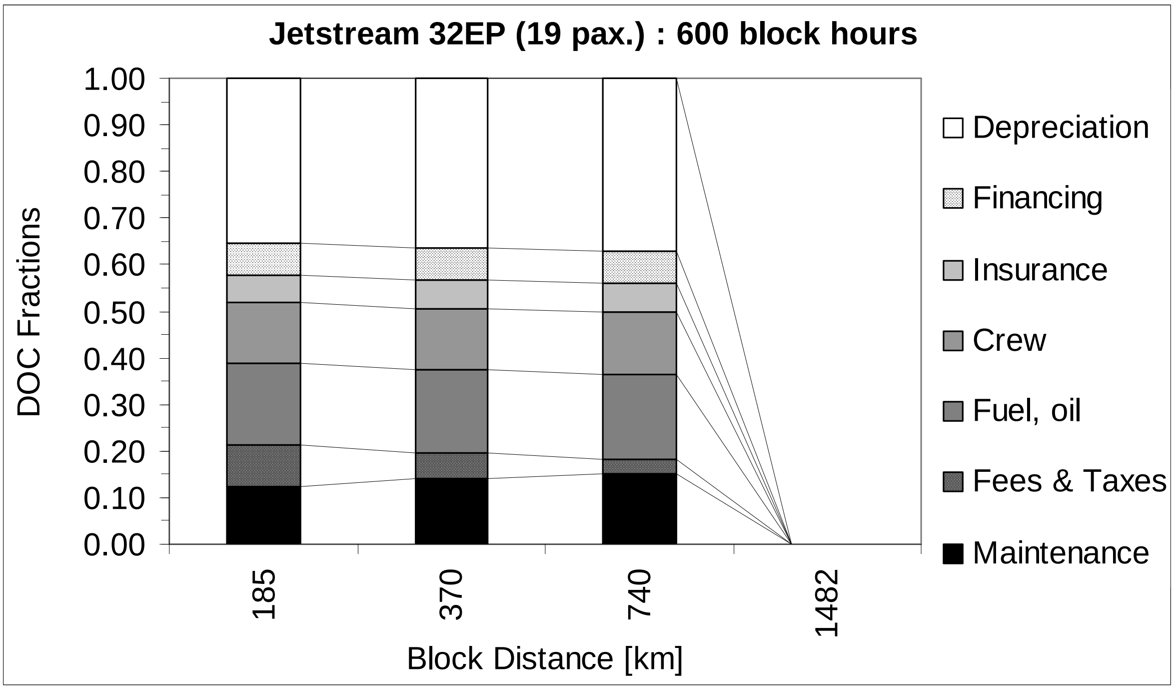


Fig.6. 28 DOC fractions changes with distance for Jetstream 32EP

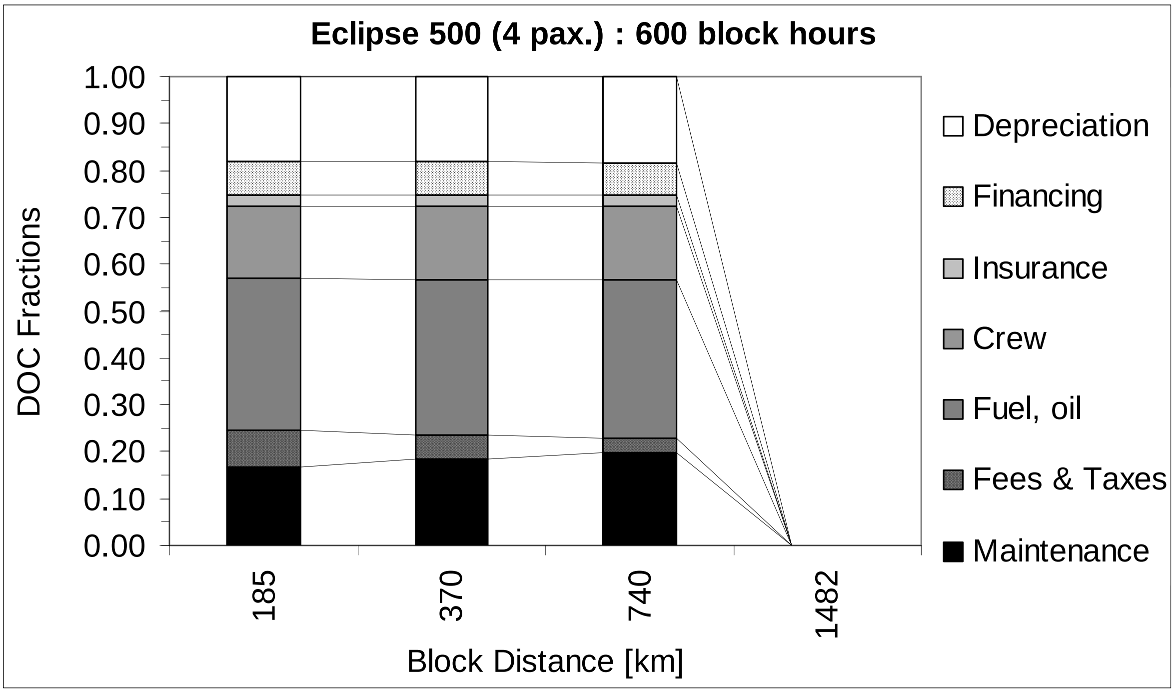


Fig.6. 29 DOC fractions changes with distance for Eclipse 500.

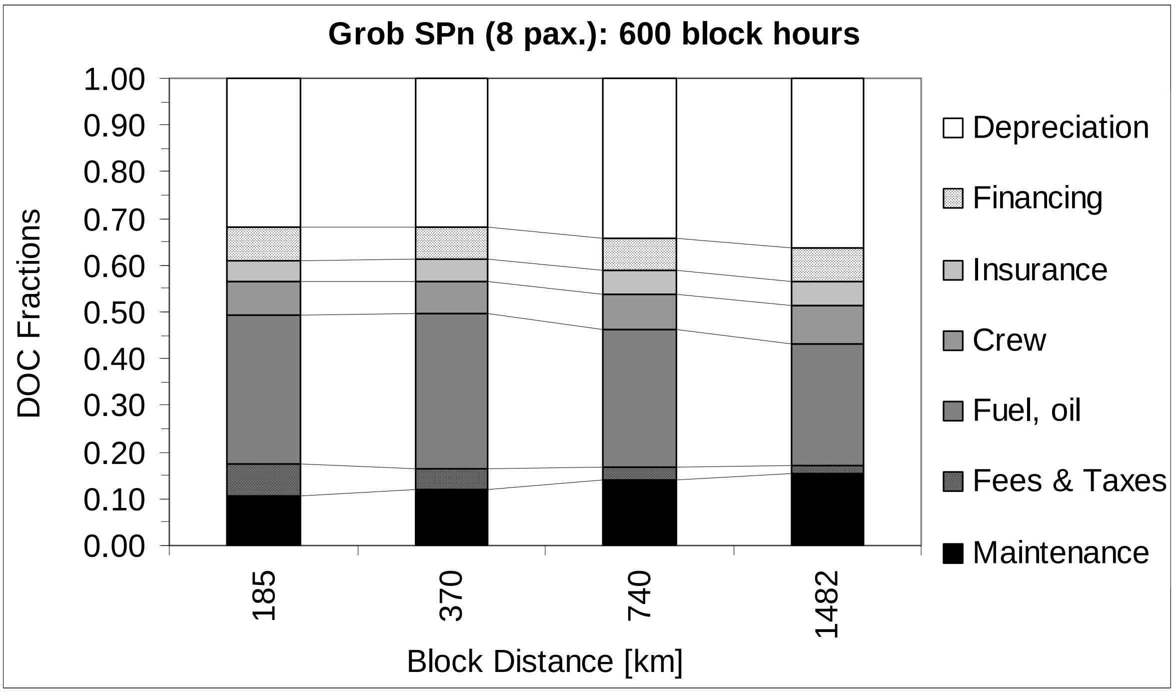


Fig.6. 30 DOC fractions changes with distance for Grob SPn

6.3.2 Direct Operating Cost Fractions - Review

- Cirrus SR-22

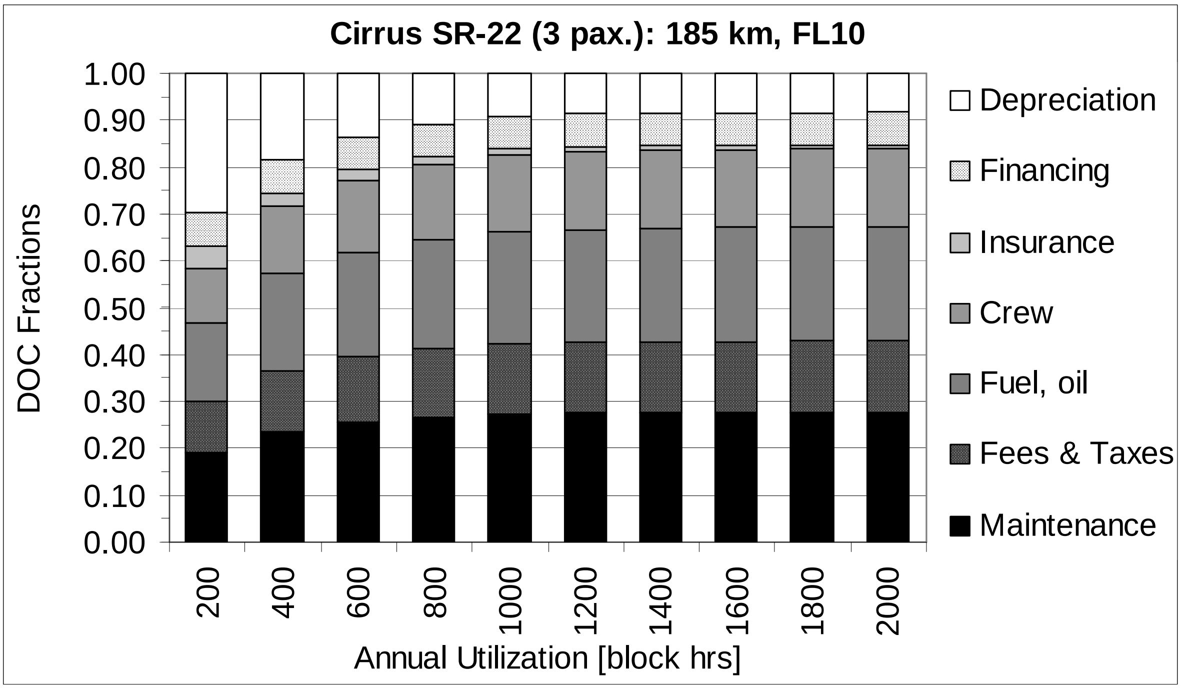


Fig.6. 31 DOC structure as function of annual utilization level for Cirrus SR-22

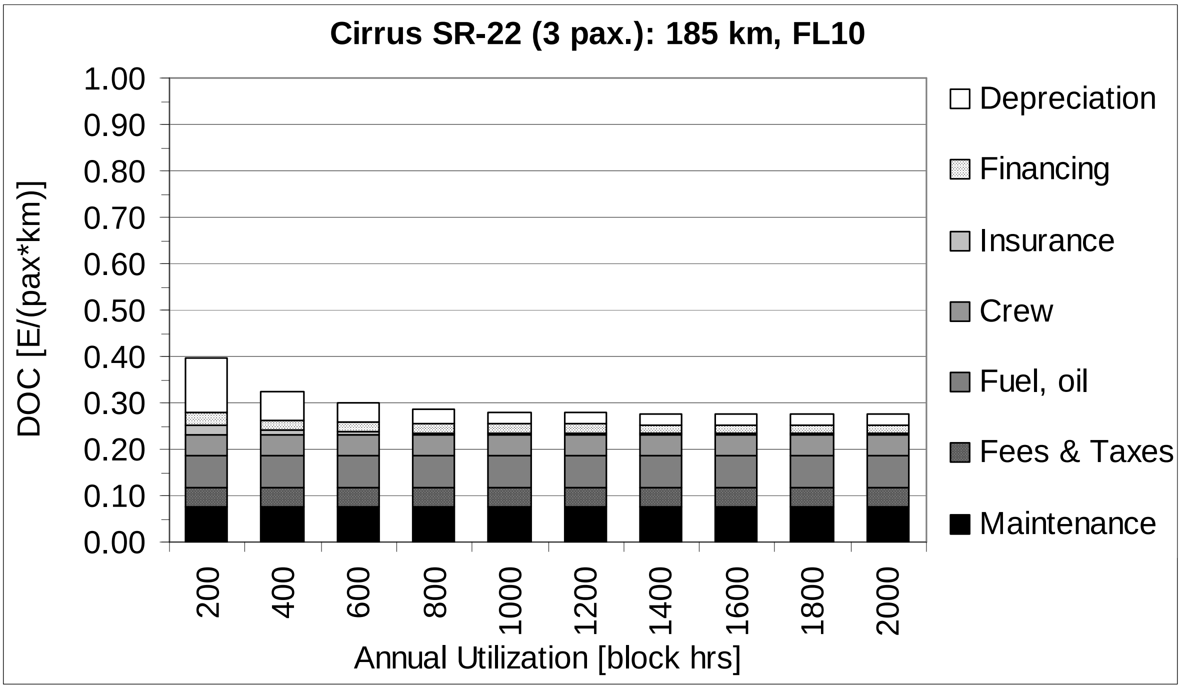


Fig.6. 32 DOC structure as function of annual utilization level for Cirrus SR-22

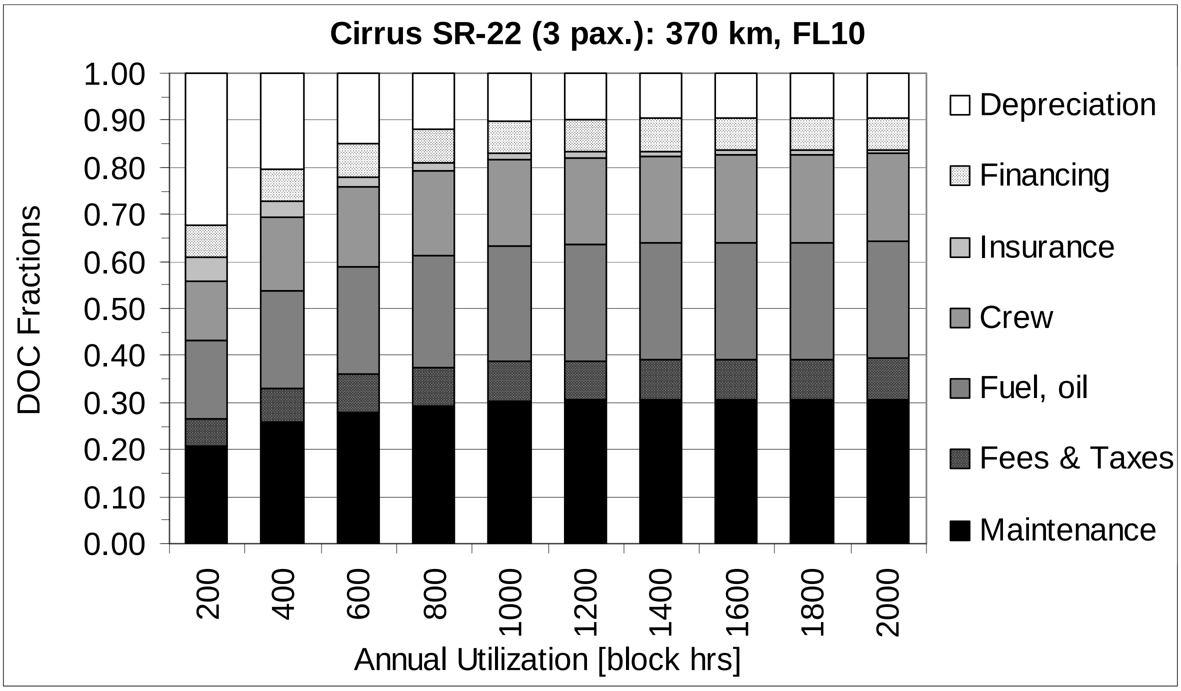


Fig.6. 33

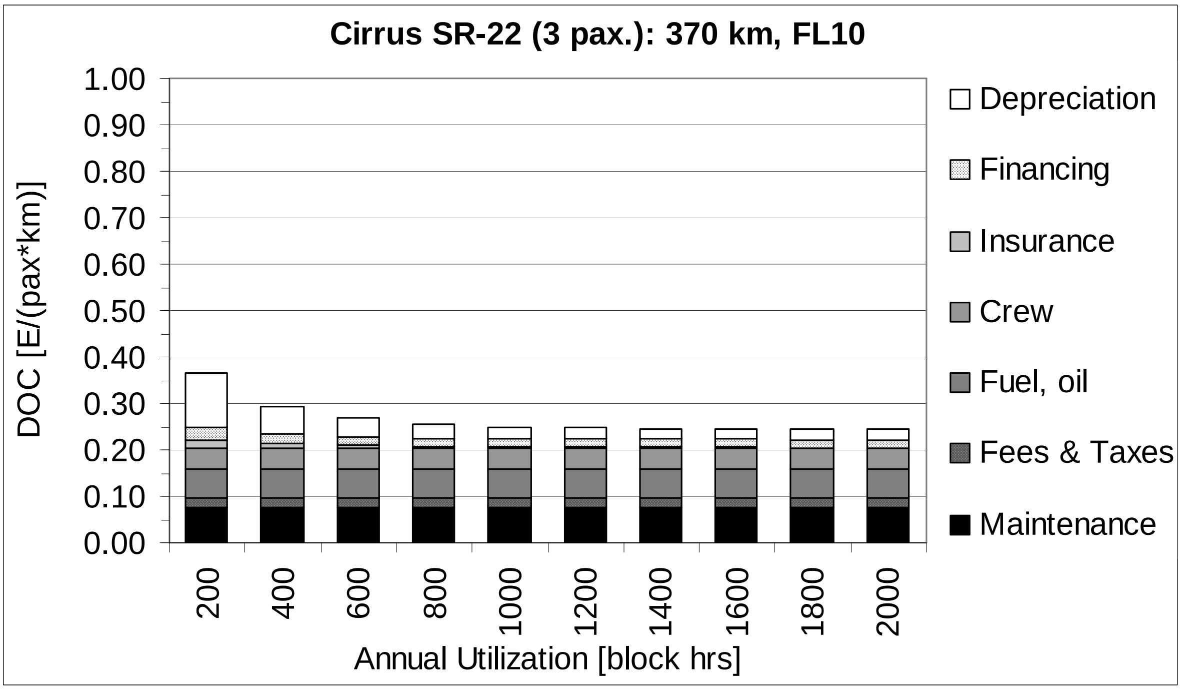


Fig.6. 34 DOC structure as function of annual utilization level for Cirrus SR-22

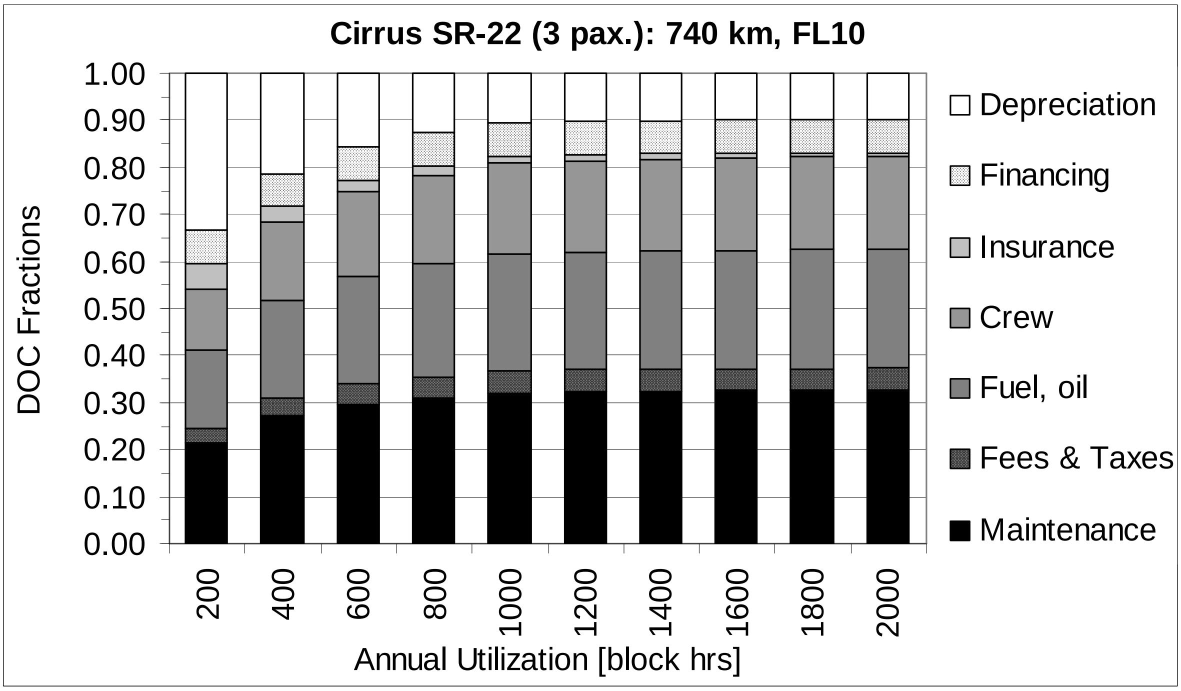


Fig.6. 35 DOC structure as function of annual utilization level for Cirrus SR-22

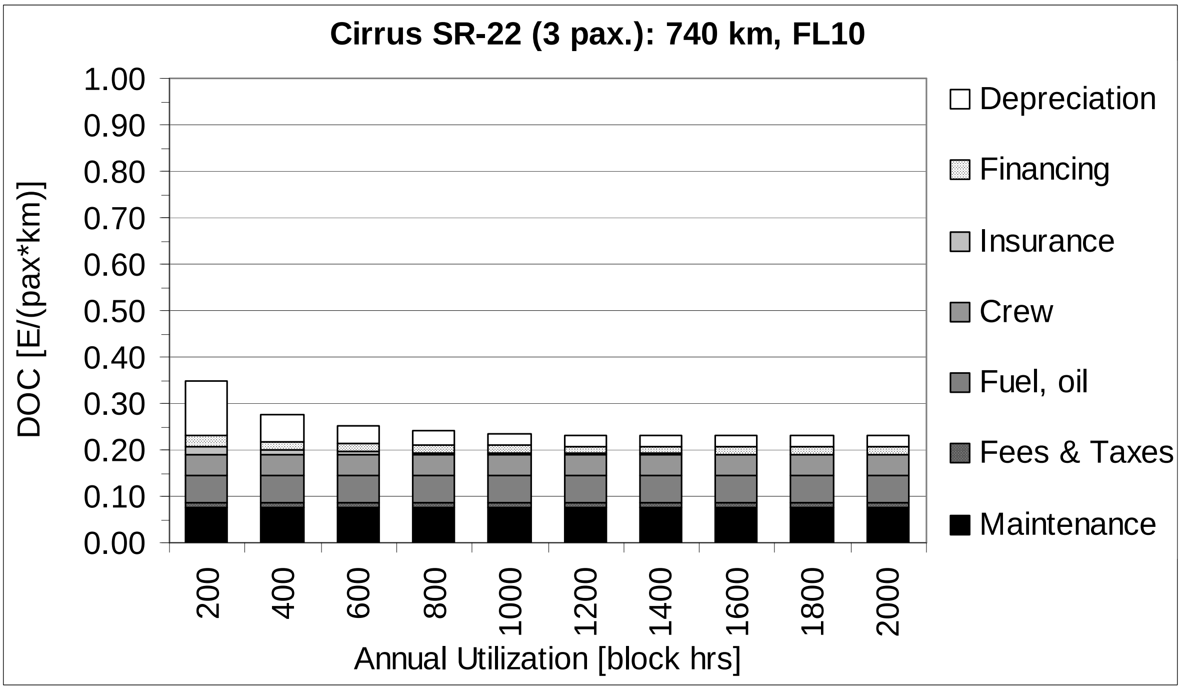


Fig.6. 36 DOC structure as function of annual utilization level for Cirrus SR-22

- Epic Dynasty

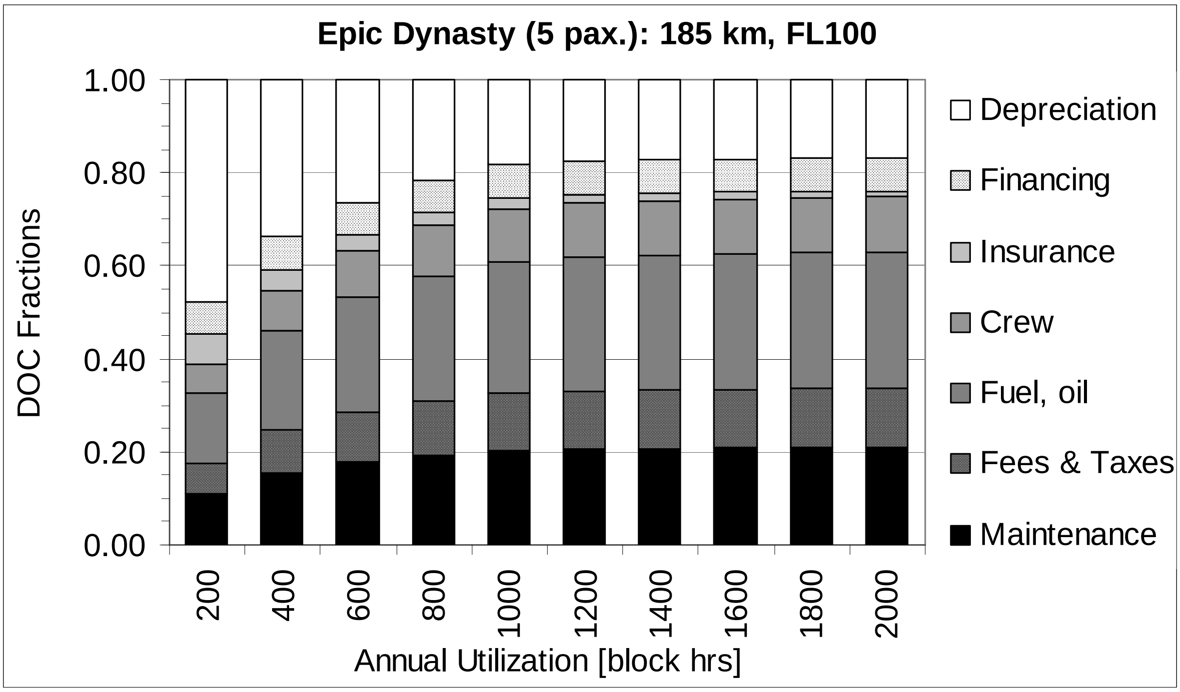


Fig.6. 37 DOC structure as function of annual utilization level for Epic Dynasty

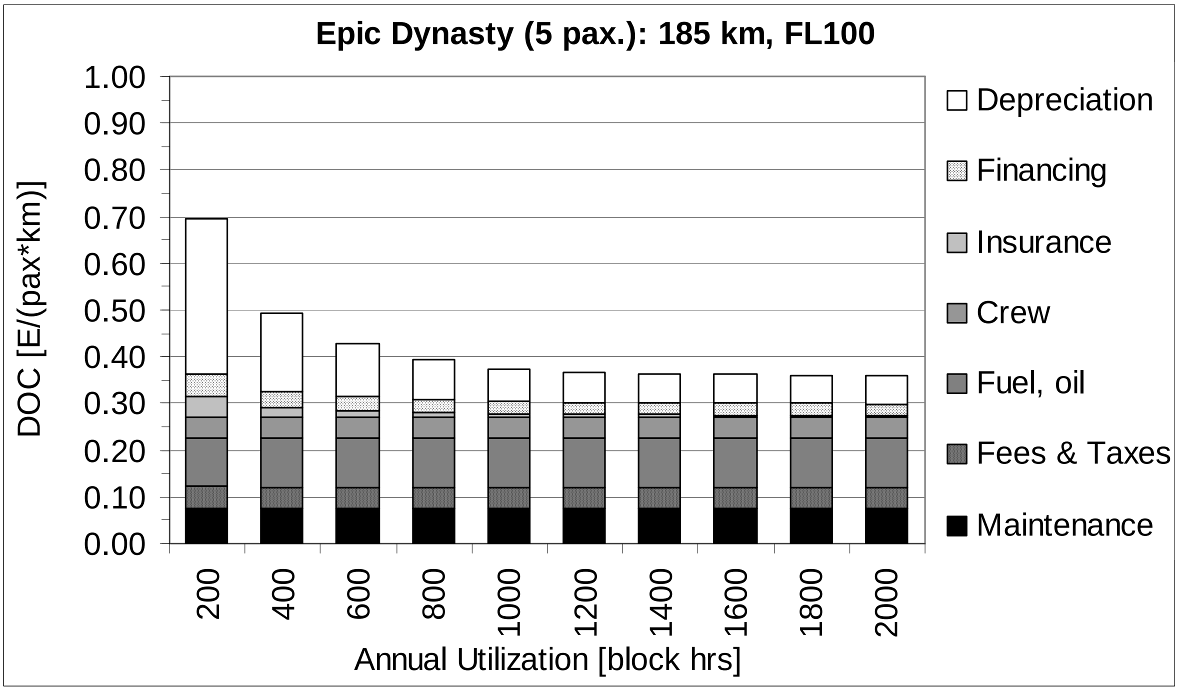


Fig.6. 38 DOC as function of annual utilization level for Epic Dynasty

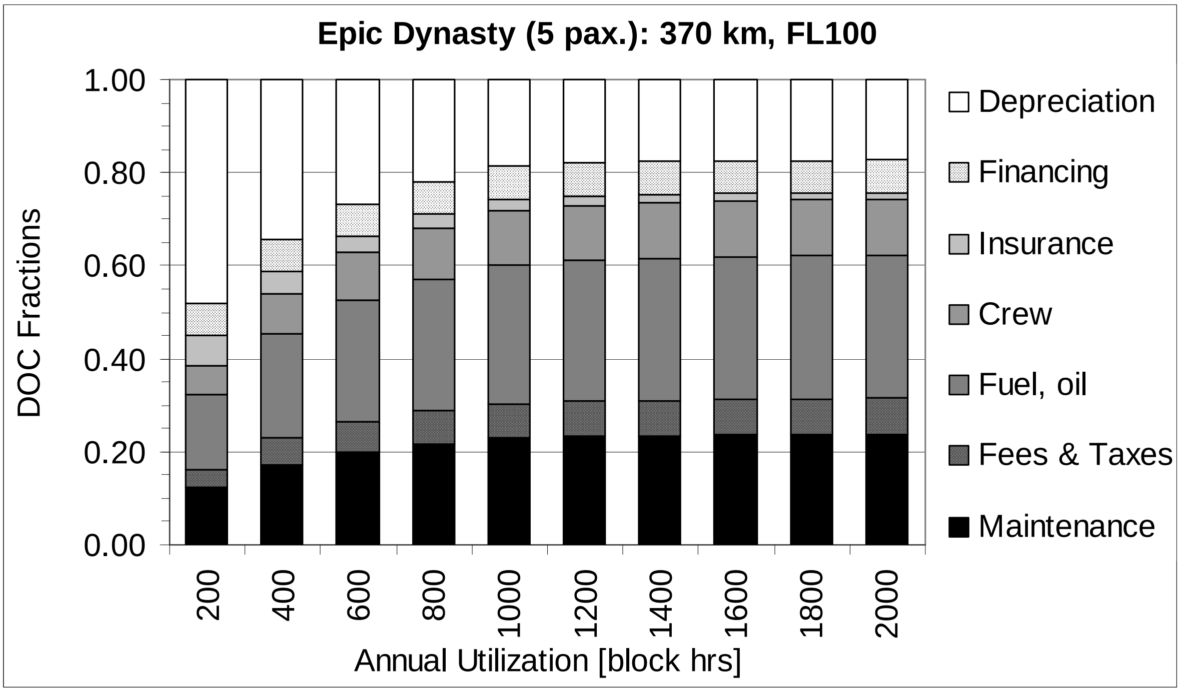


Fig.6. 39 DOC structure as function of annual utilization level for Epic Dynasty

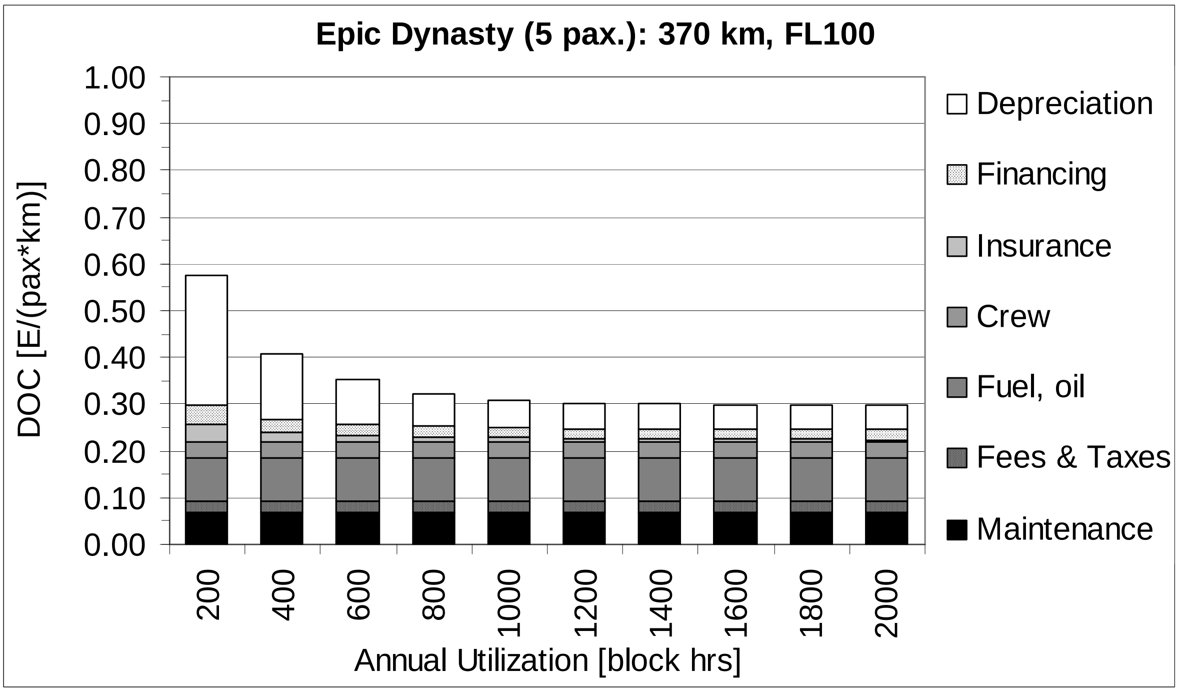


Fig.6. 40 DOC as function of annual utilization level for Epic Dynasty

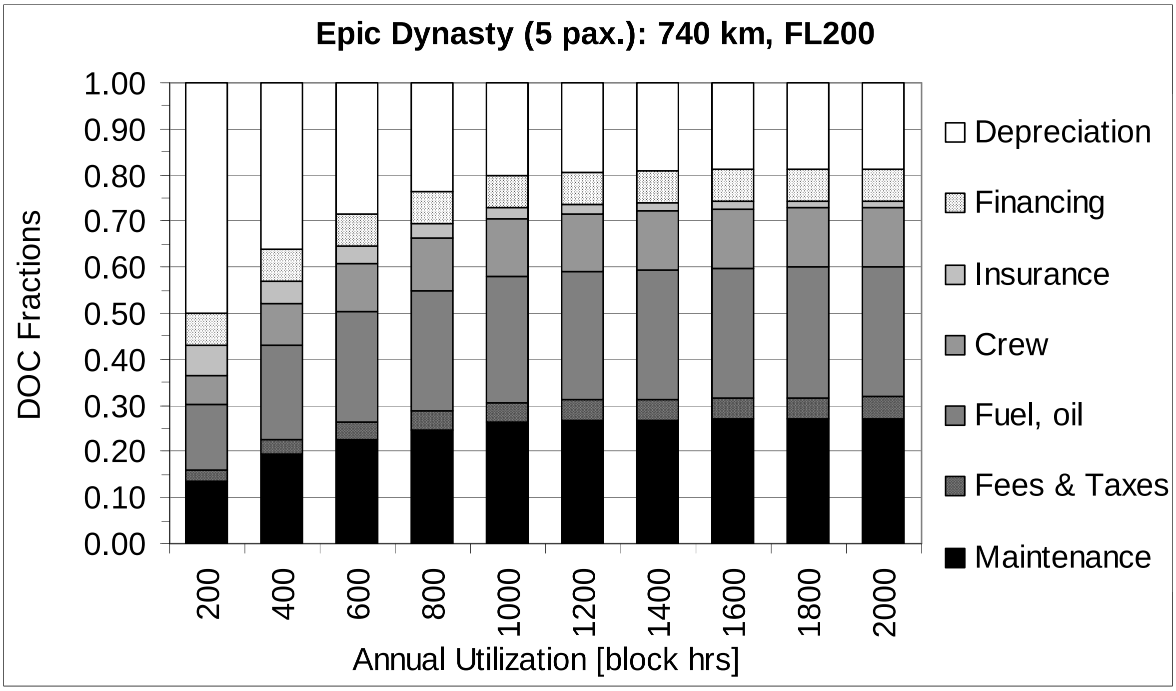


Fig.6. 41 DOC structure as function of annual utilization level for Epic Dynasty

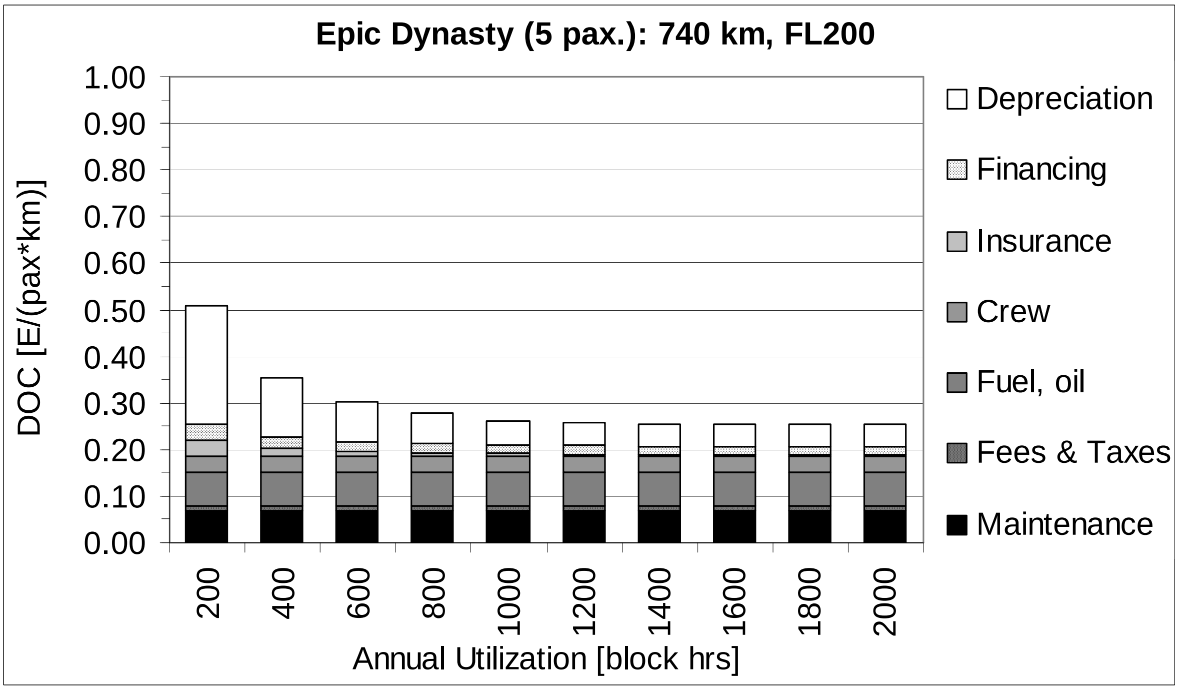


Fig.6. 42 DOC as function of annual utilization level for Epic Dynasty

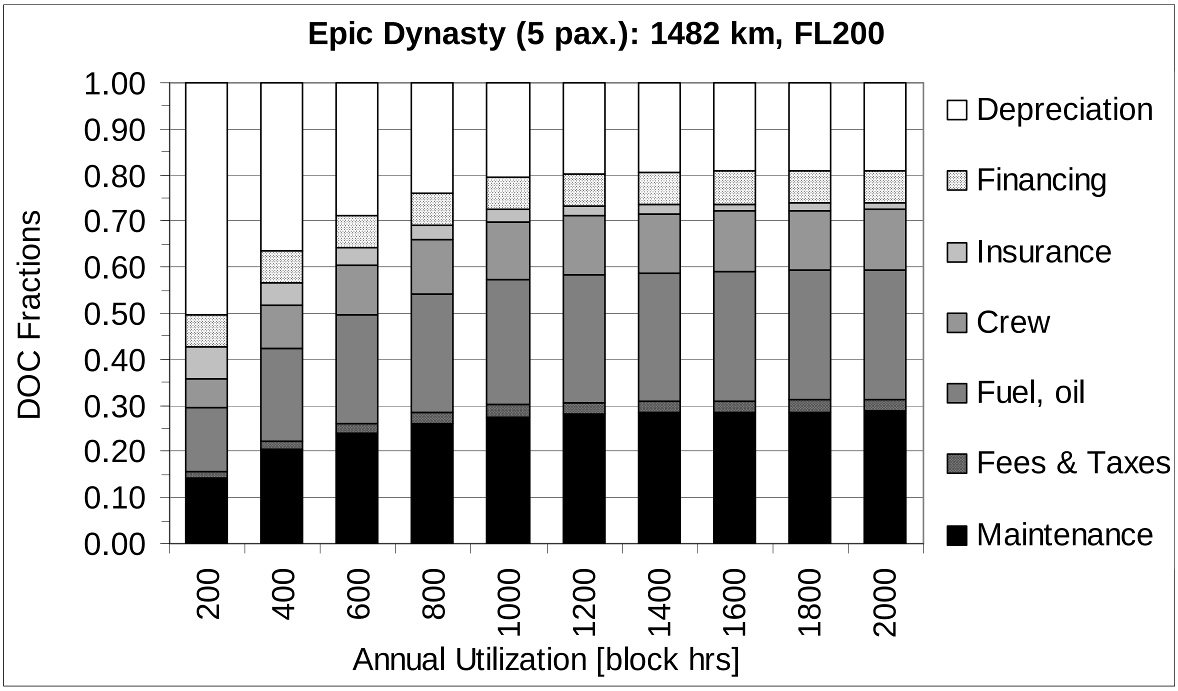


Fig.6. 43 DOC structure as function of annual utilization level for Epic Dynasty

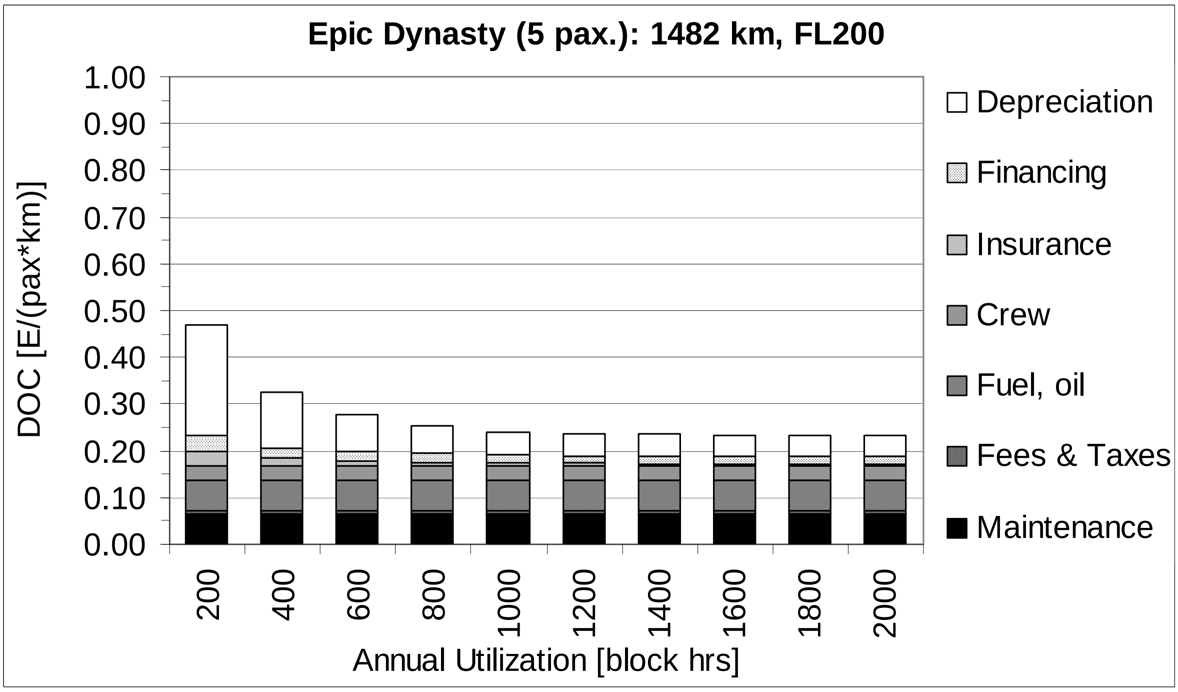


Fig.6. 44 DOC as function of annual utilization level for Epic Dynasty

- Pilatus PC-12

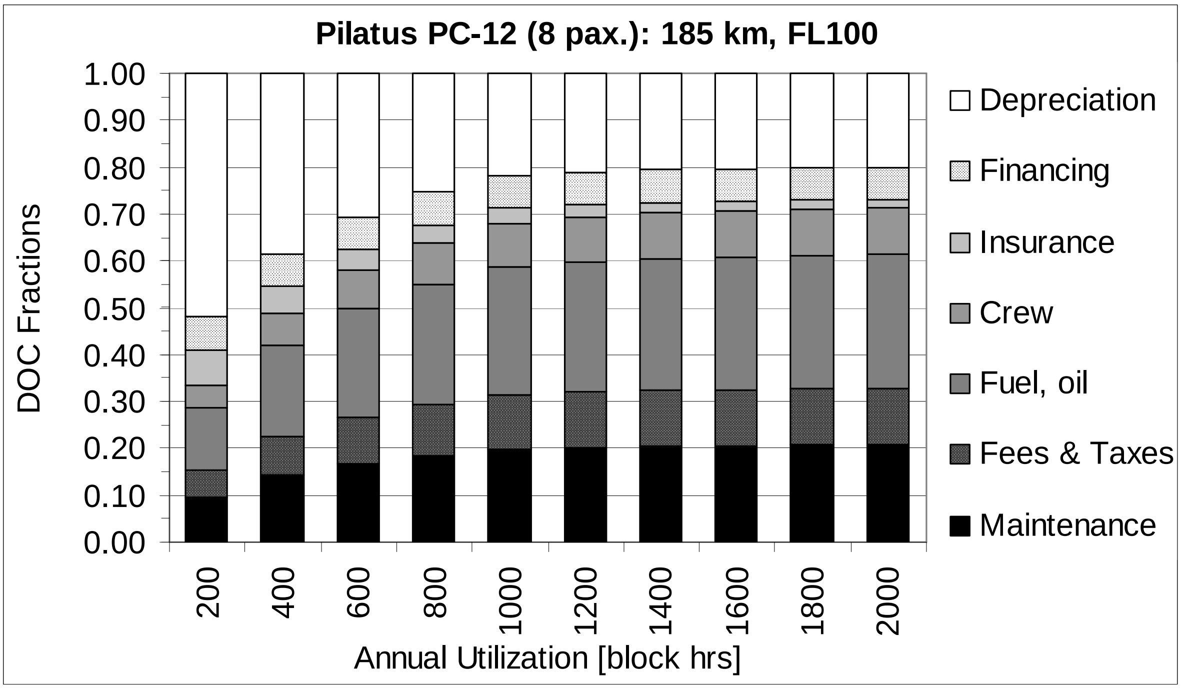


Fig.6. 45 DOC structure as function of annual utilization level for Pilatus PC-12

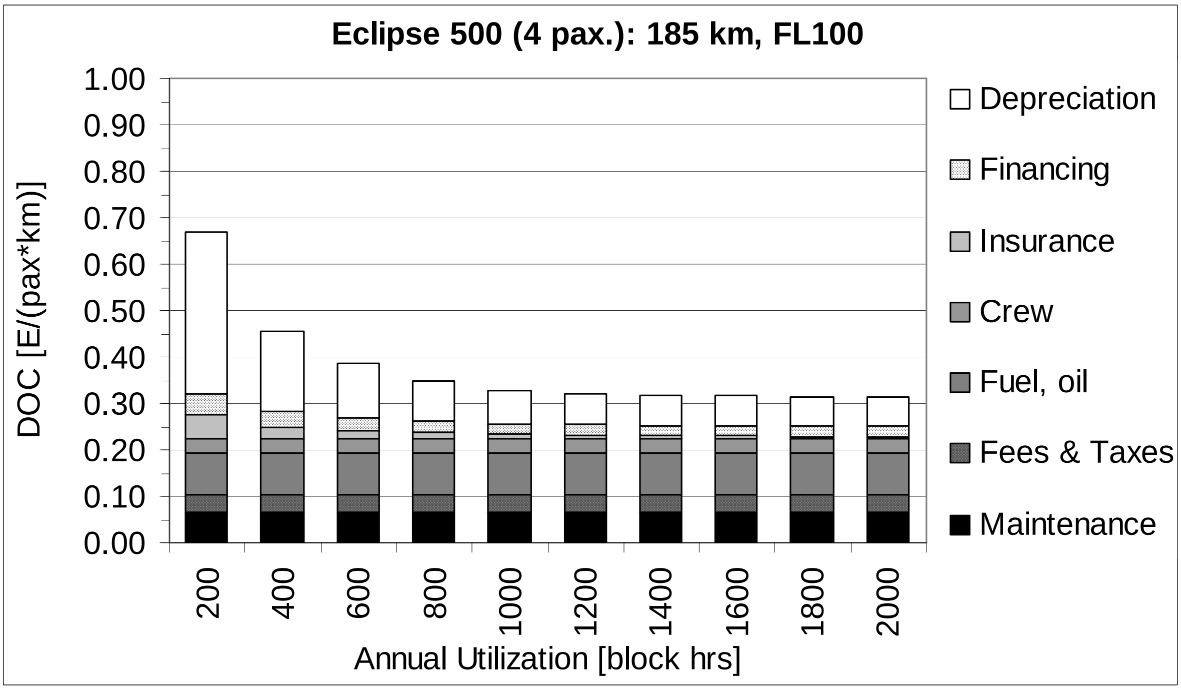


Fig.6. 46 DOC structure as function of annual utilization level for Pilatus PC-12

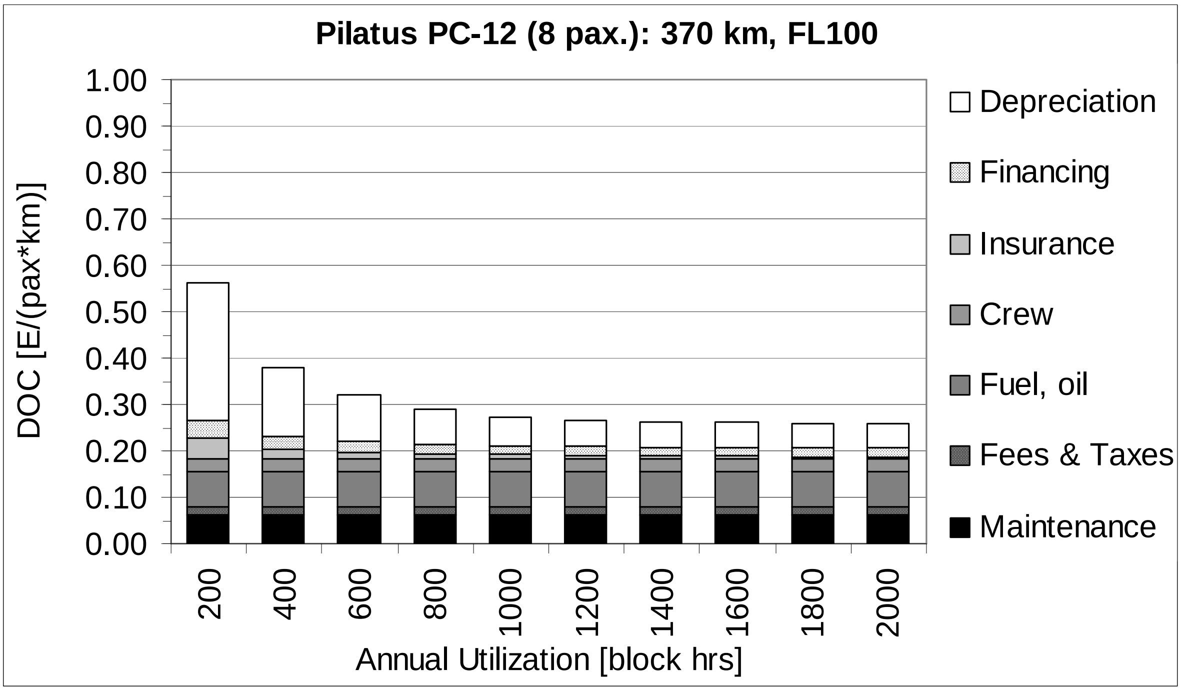


Fig.6. 47 DOC structure as function of annual utilization level for Pilatus PC-12

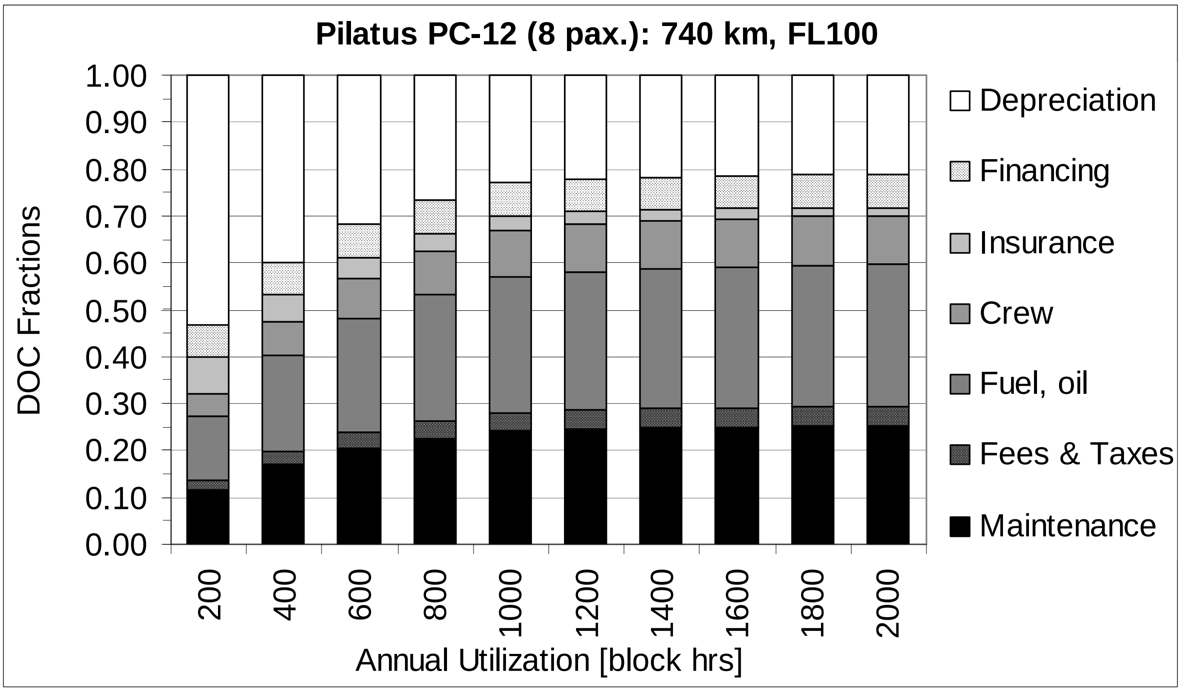


Fig.6. 48 DOC structure as function of annual utilization level for Pilatus PC-12

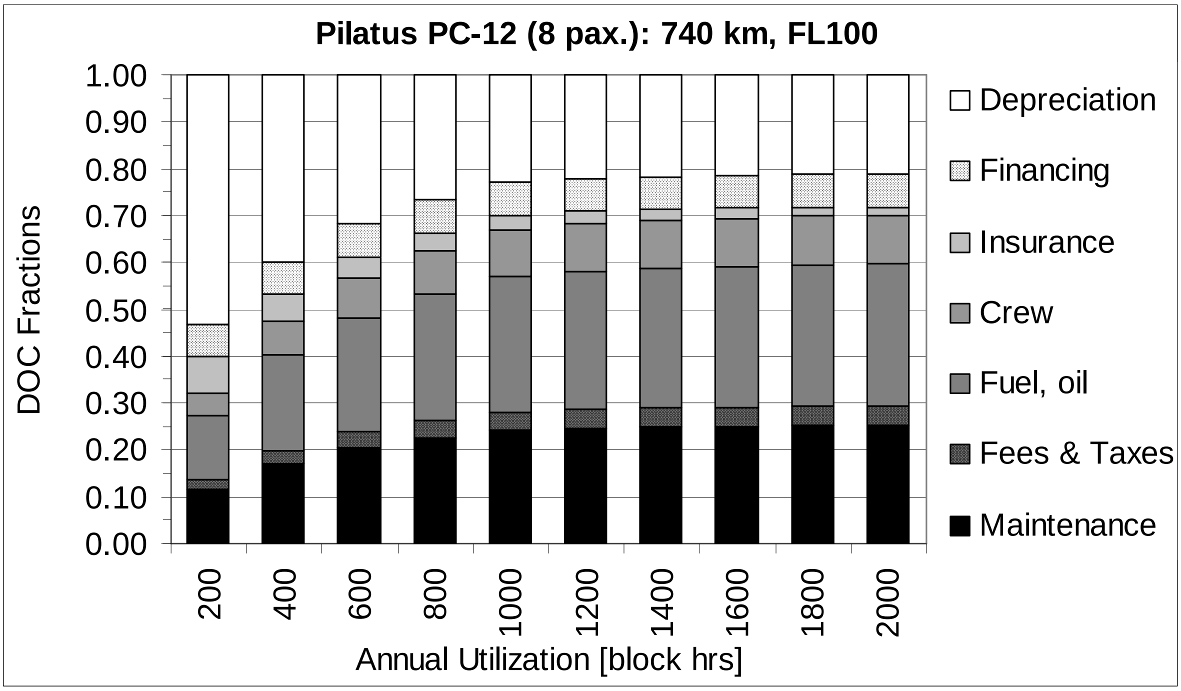


Fig.6. 49 DOC structure as function of annual utilization level for Pilatus PC-12

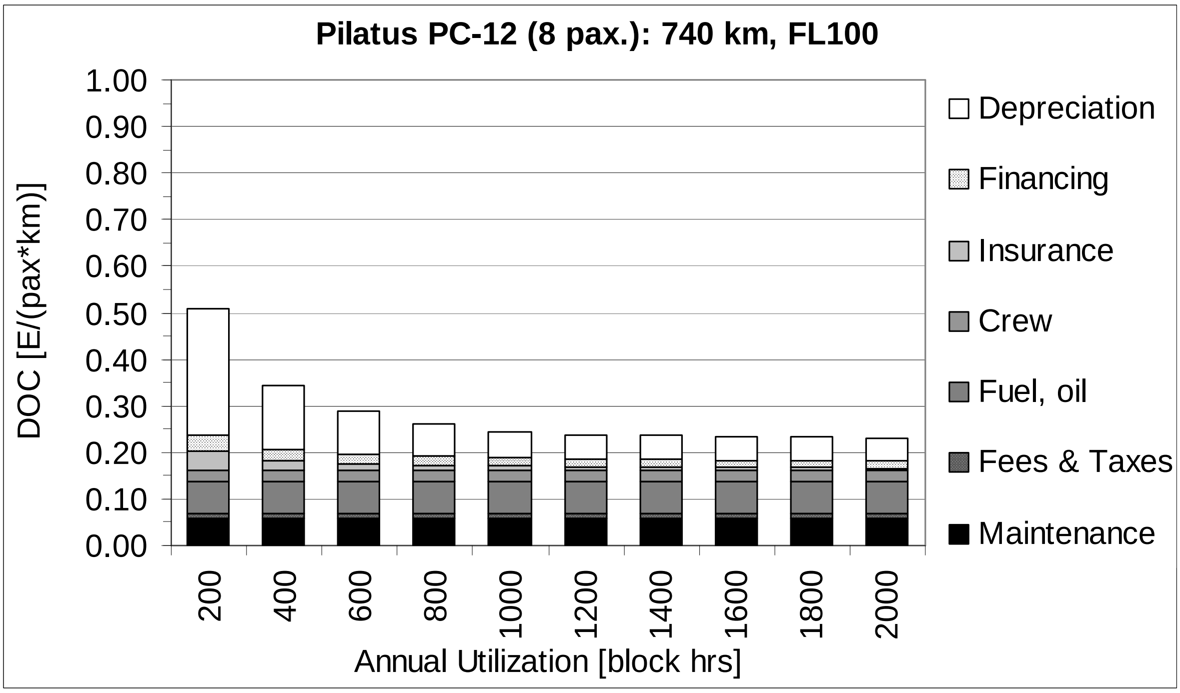


Fig.6. 50 DOC structure as function of annual utilization level for Pilatus PC-12

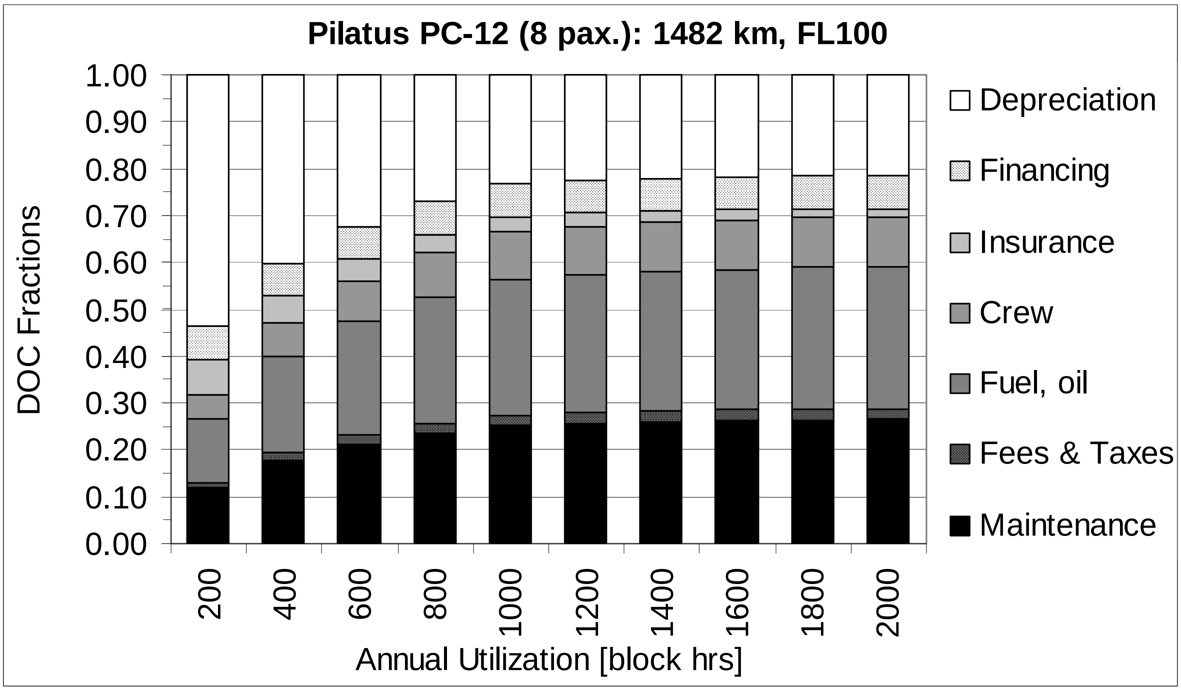


Fig.6. 51 DOC structure as function of annual utilization level for Pilatus PC-12

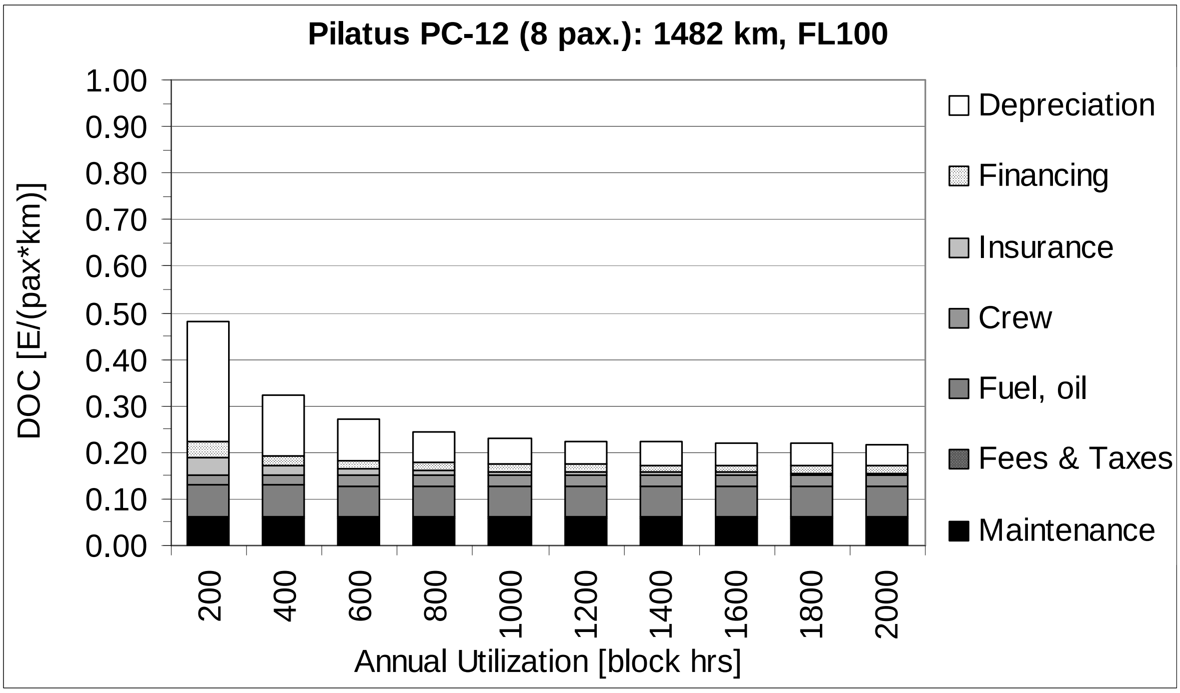


Fig.6. 52 DOC structure as function of annual utilization level for Pilatus PC-12

- Piaggio Avanti II

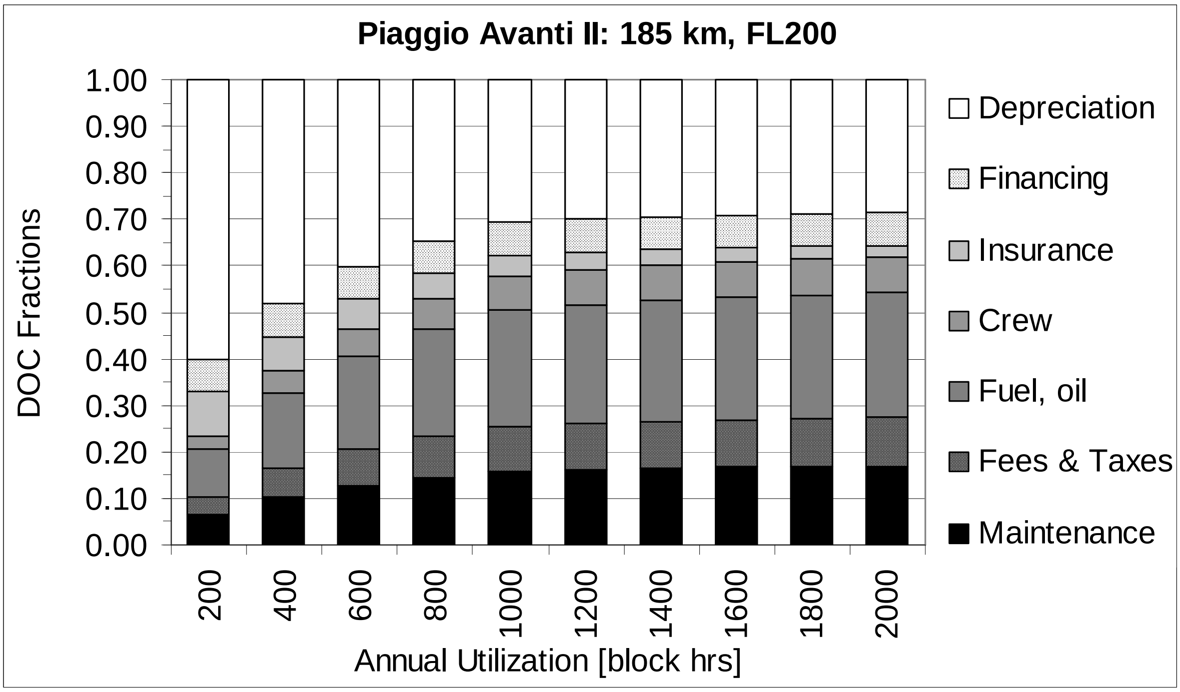


Fig.6. 53 DOC structure as function of annual utilization level for Piaggio Avanti

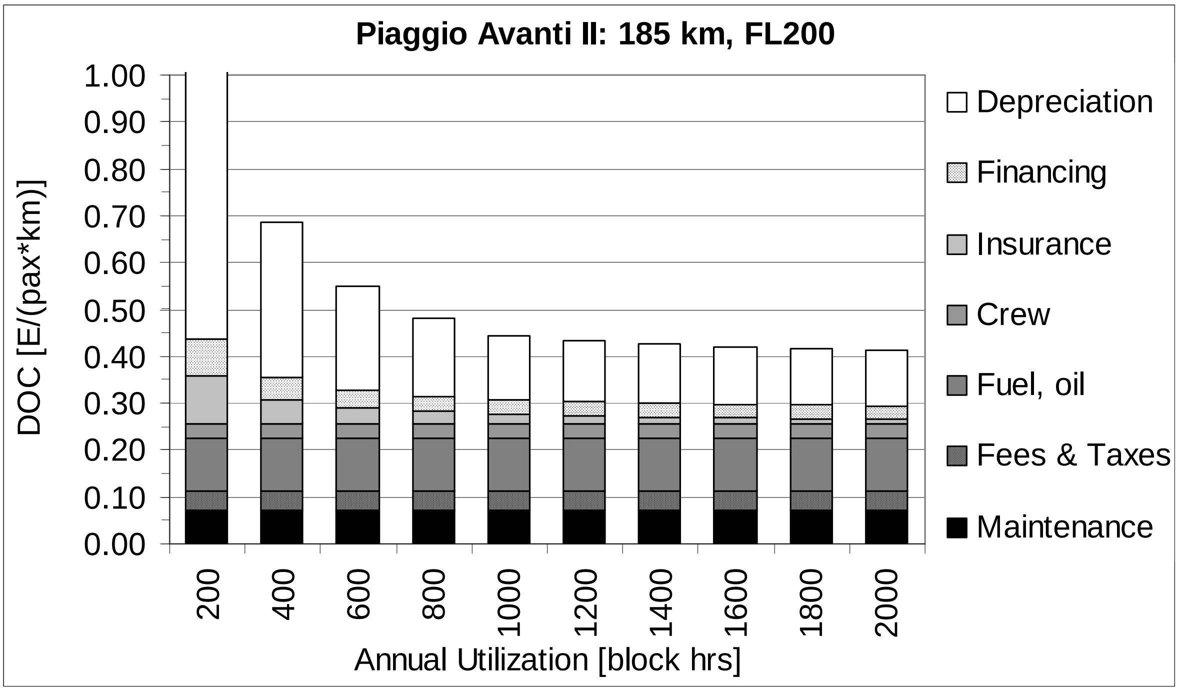


Fig.6. 54 DOC as function of annual utilization level for Piaggio Avanti

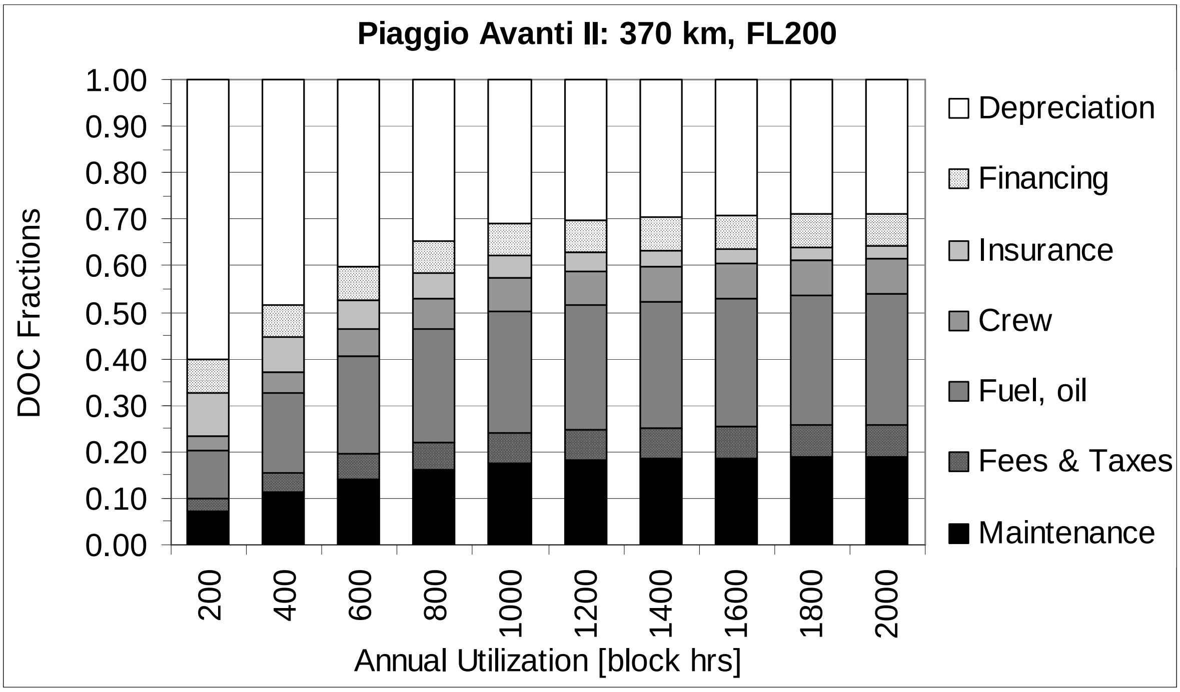


Fig.6. 55 DOC structure as function of annual utilization level for Piaggio Avanti

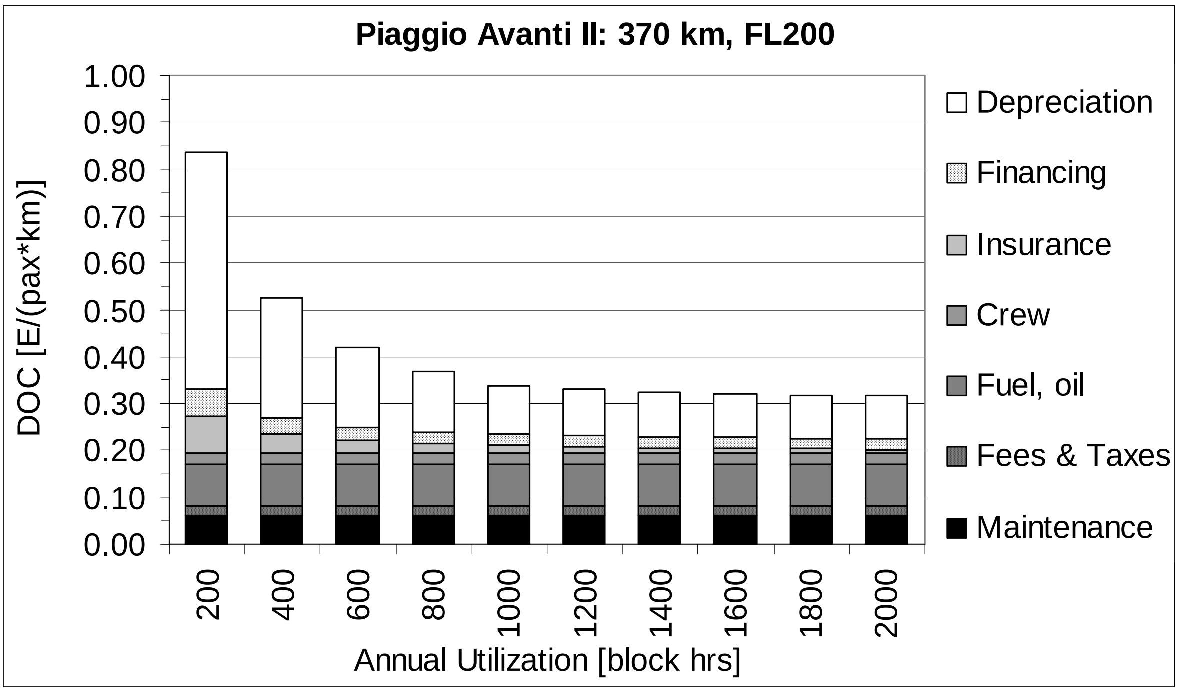


Fig.6. 56 DOC as function of annual utilization level for Piaggio Avanti

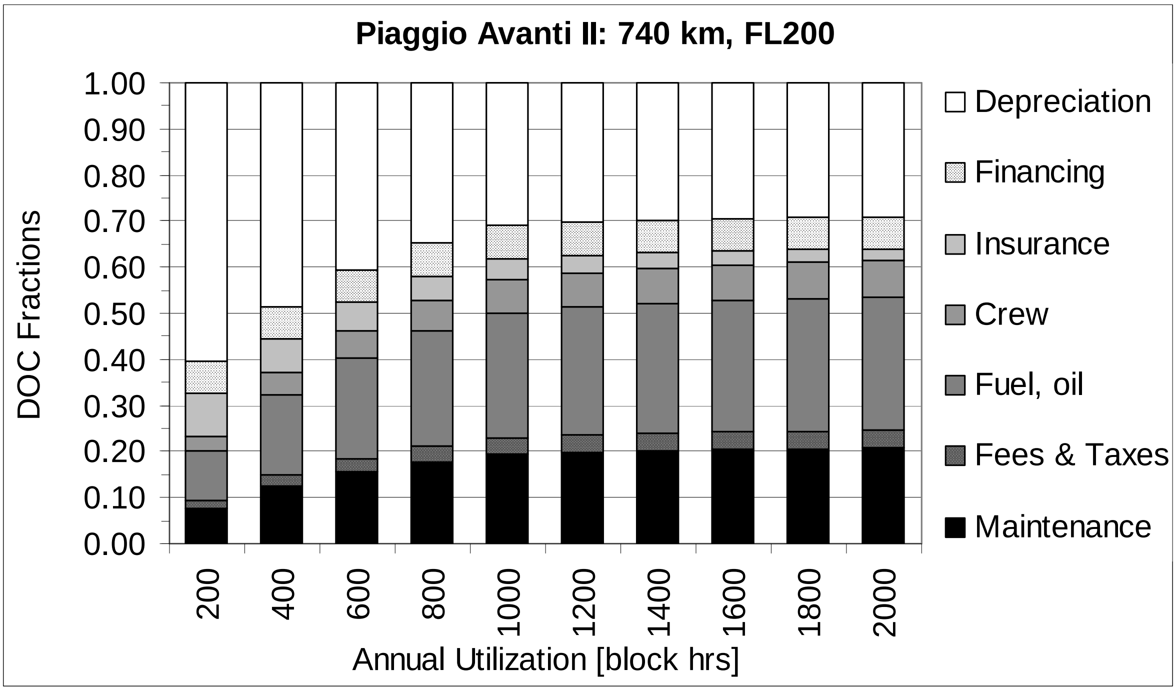


Fig.6. 57 DOC structure as function of annual utilization level for Piaggio Avanti

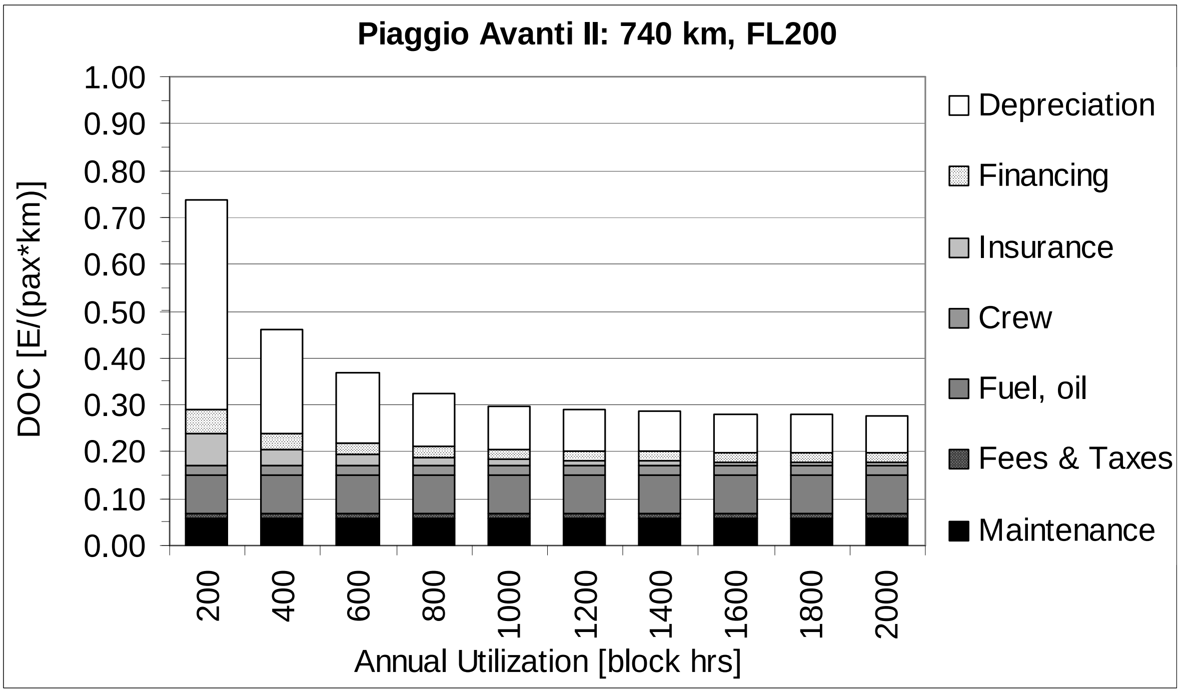


Fig.6. 58 DOC as function of annual utilization level for Piaggio Avanti

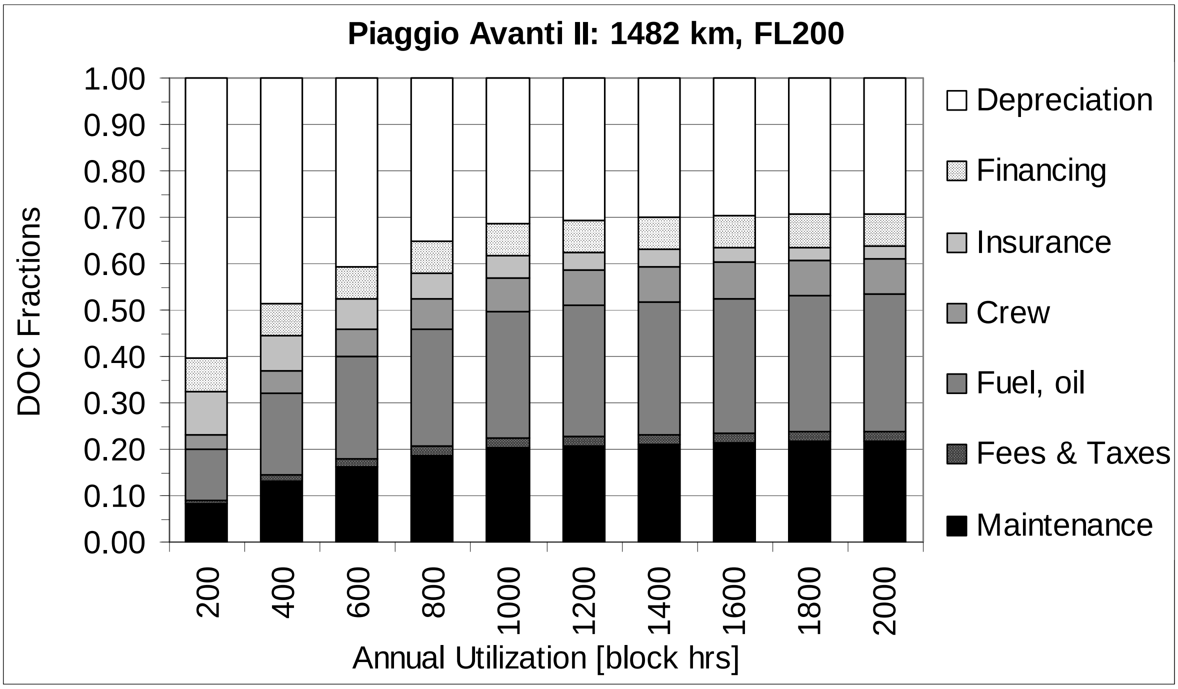


Fig.6. 59 DOC structure as function of annual utilization level for Piaggio Avanti

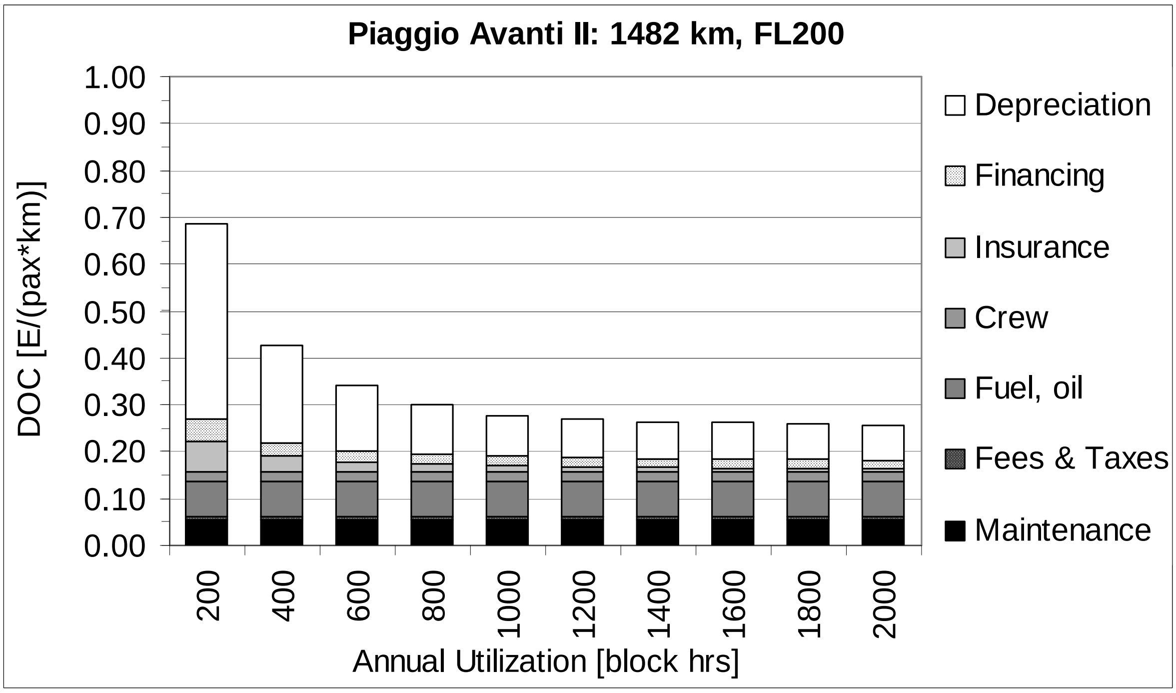


Fig.6. 60 DOC as function of annual utilization level for Piaggio Avanti

- Jetstream 32EP

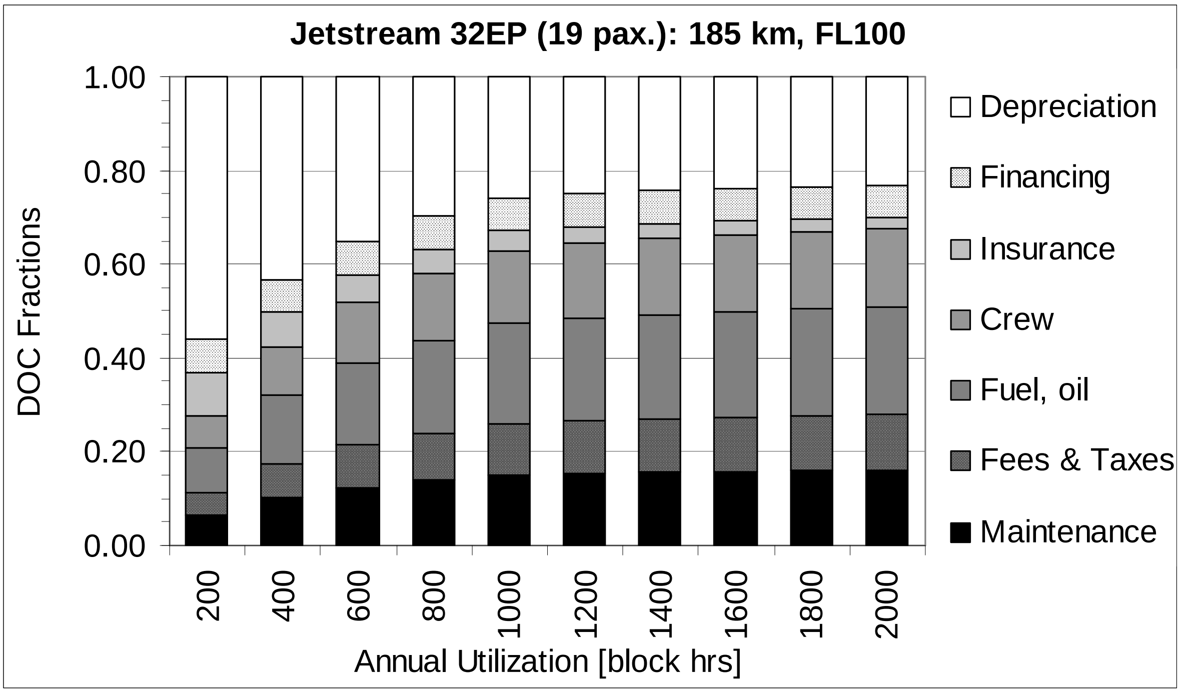


Fig.6. 61 DOC as function of annual utilization level for Jetstream 32EP

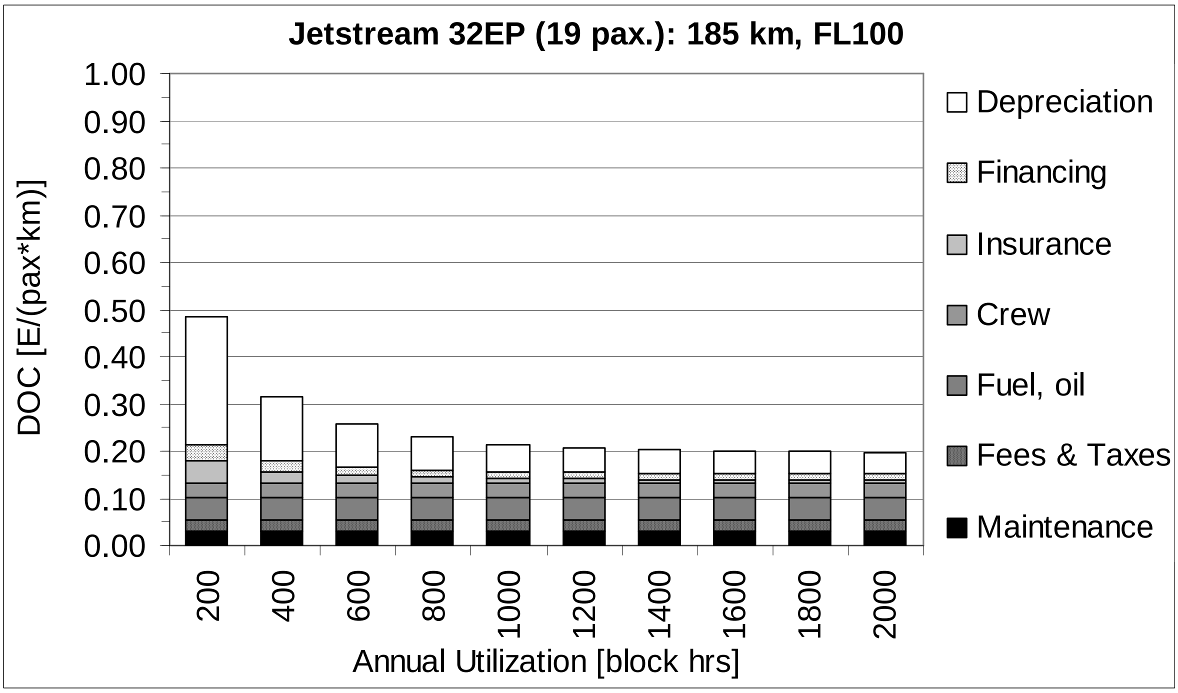


Fig.6. 62 DOC as function of annual utilization level for Jetstream 32EP

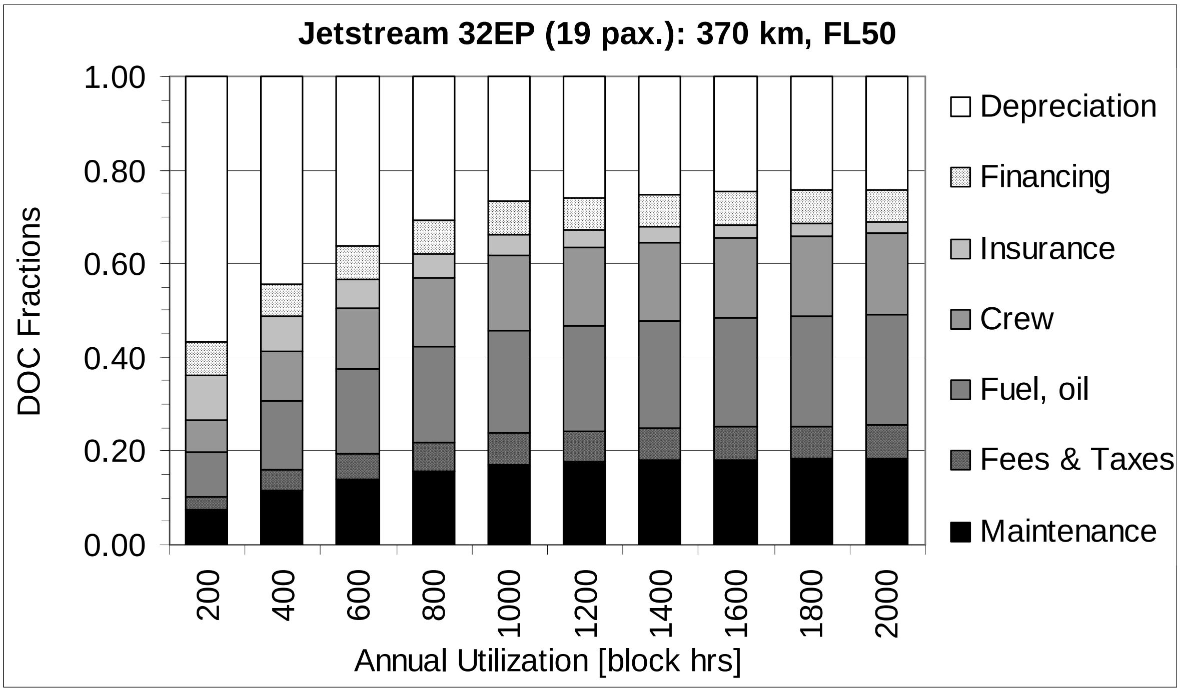


Fig.6. 63 DOC as function of annual utilization level for Jetstream 32EP

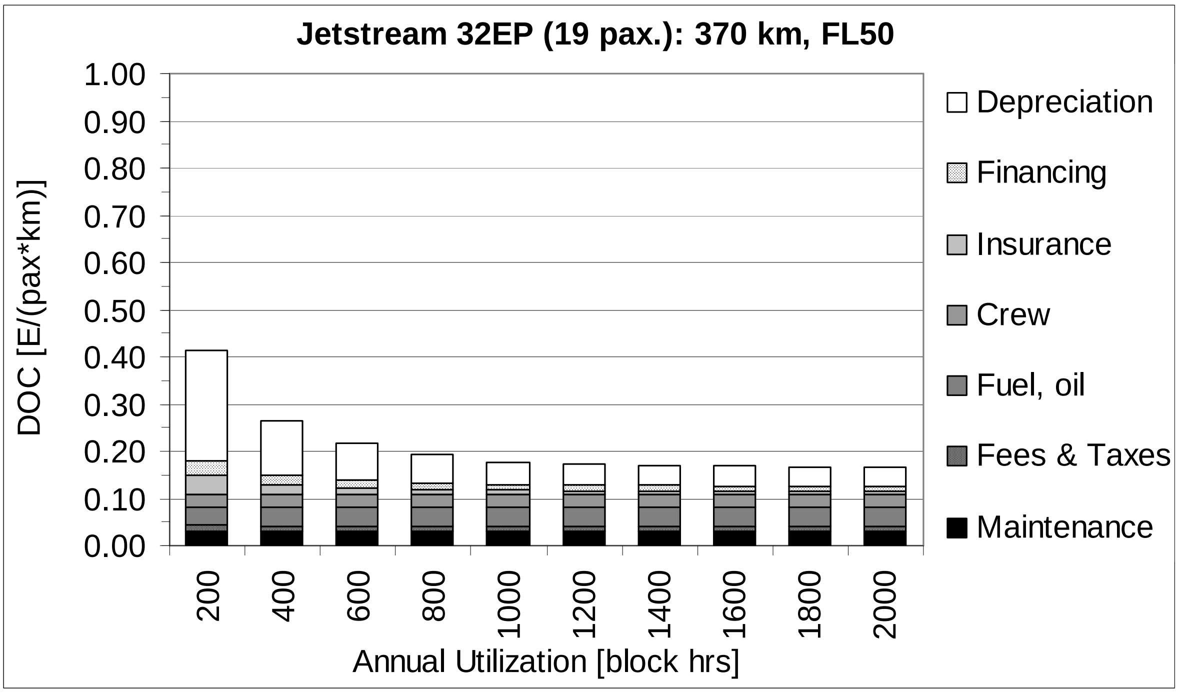


Fig.6. 64 DOC as function of annual utilization level for Jetstream 32EP

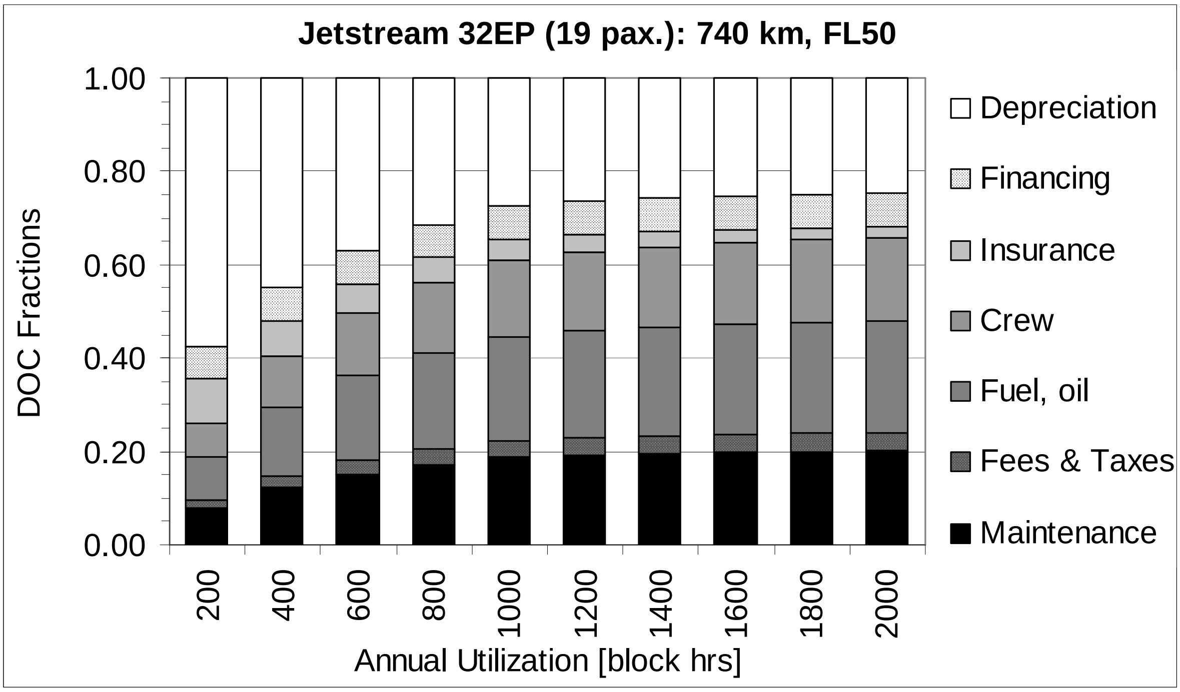


Fig.6. 65 DOC as function of annual utilization level for Jetstream 32EP

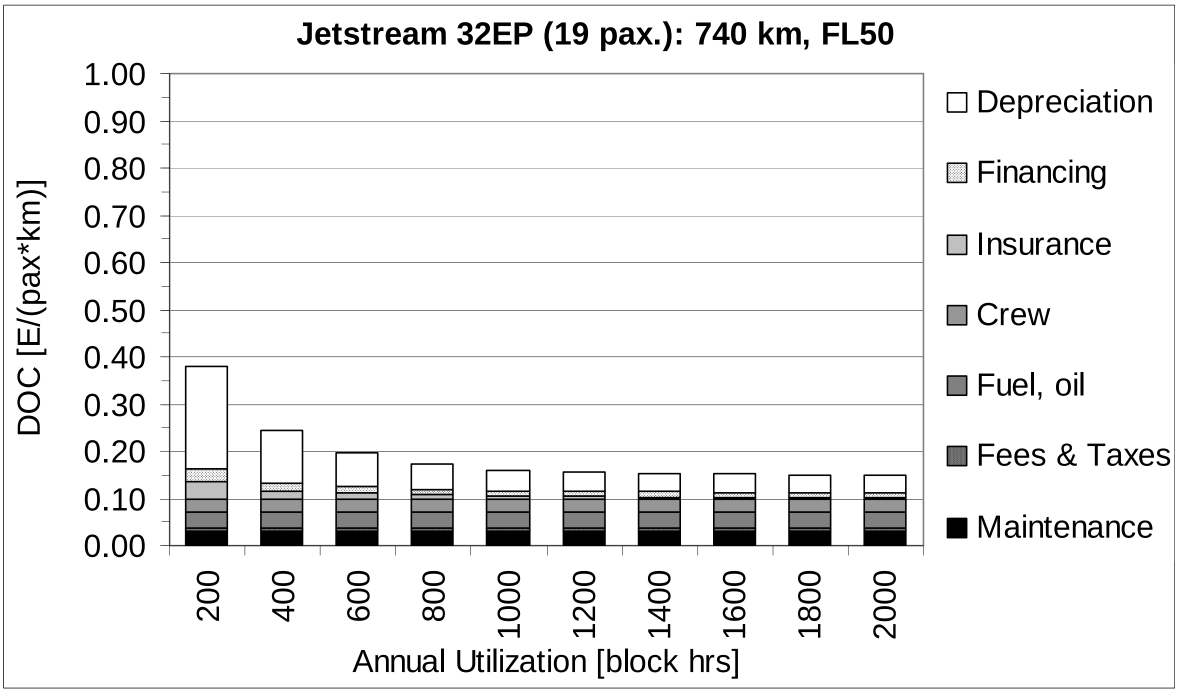


Fig.6. 66 DOC as function of annual utilization level for Jetstream 32EP

- Eclipse 500

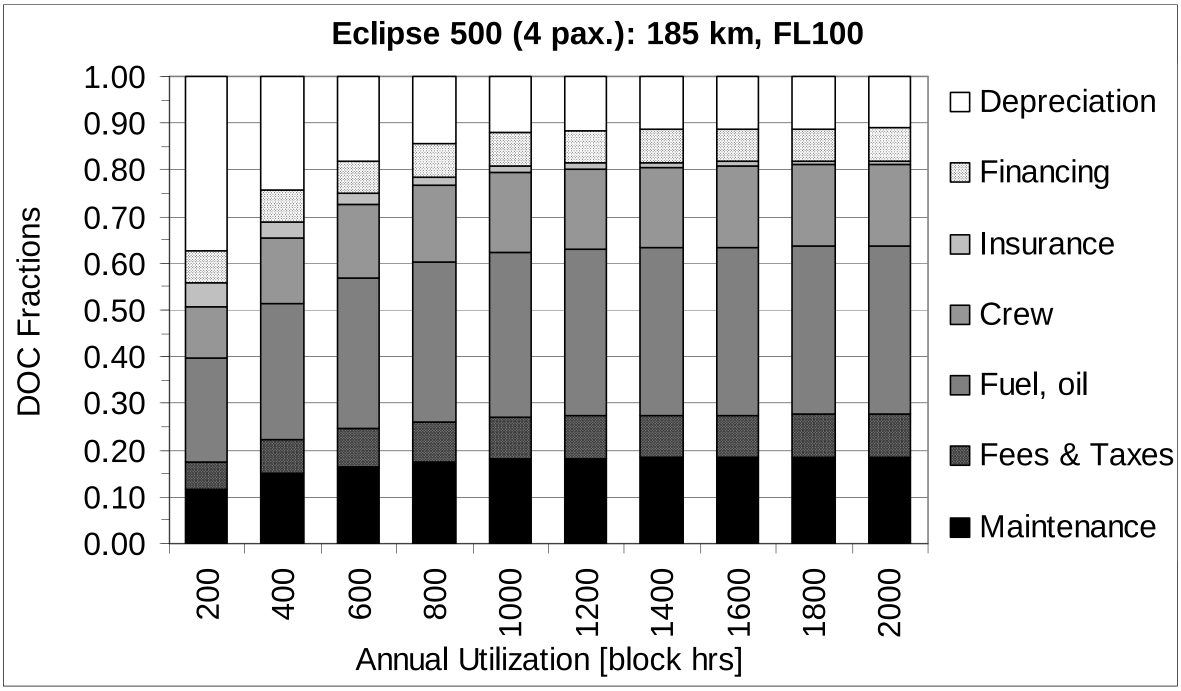


Fig.6. 67 DOC structure as function of annual utilization level for Eclipse 500

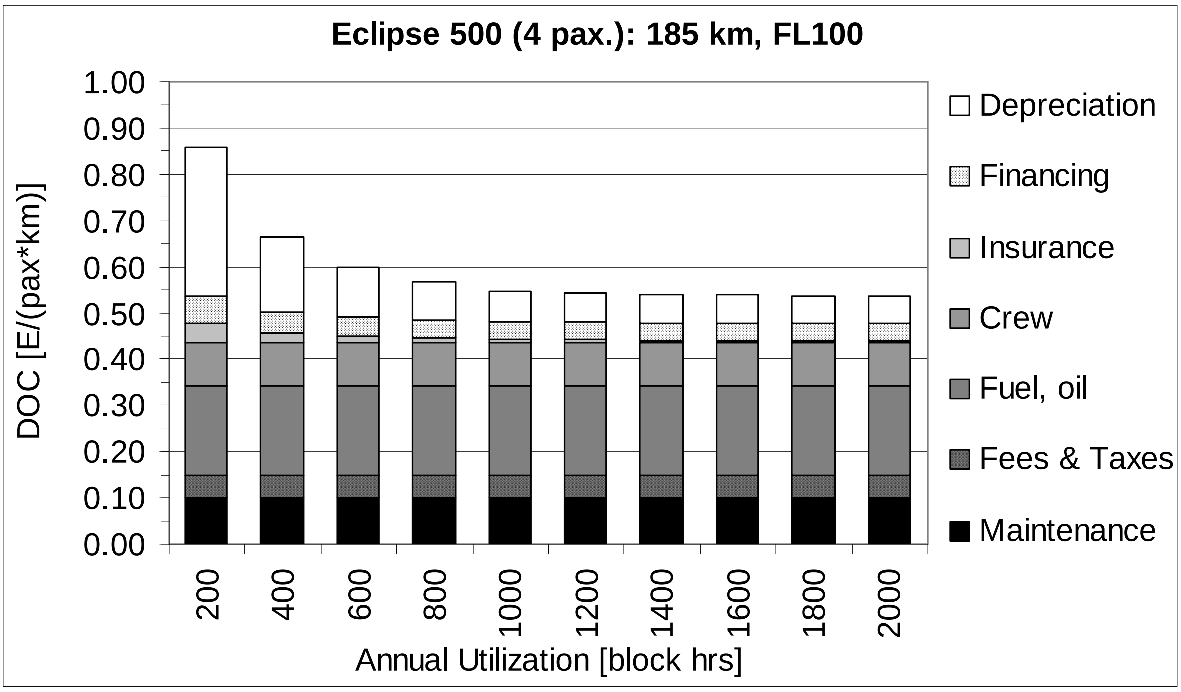


Fig.6. 68 DOC as function of annual utilization level for Eclipse 500

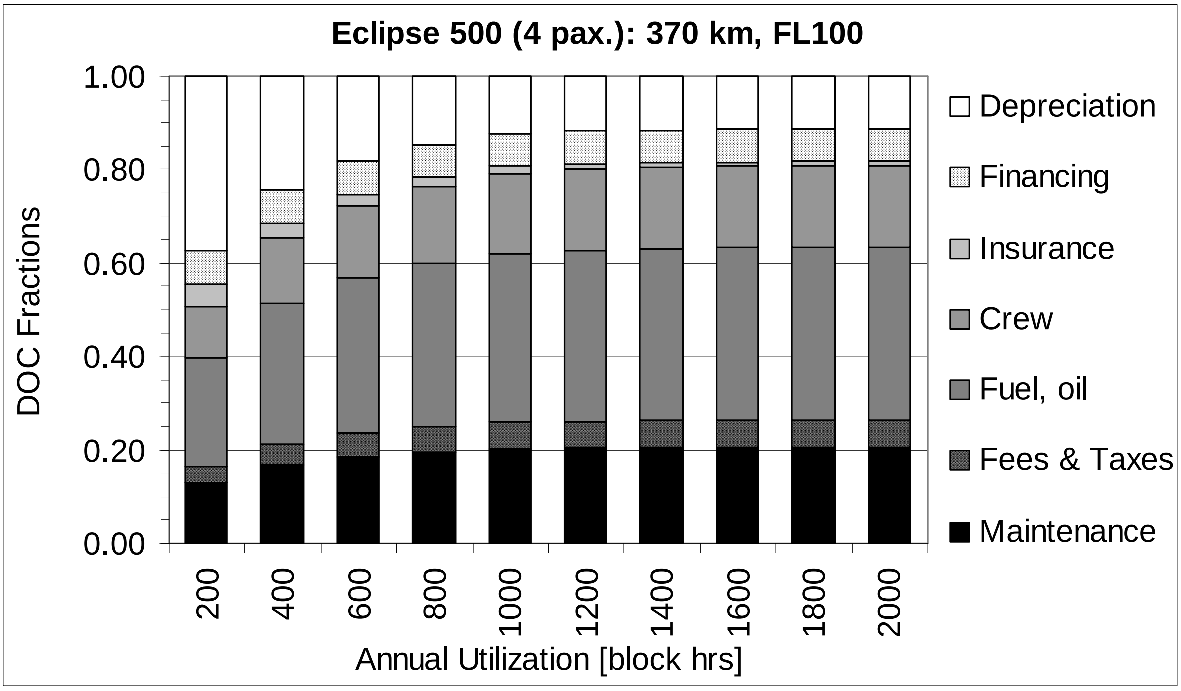


Fig.6. 69 DOC structure as function of annual utilization level for Eclipse 500

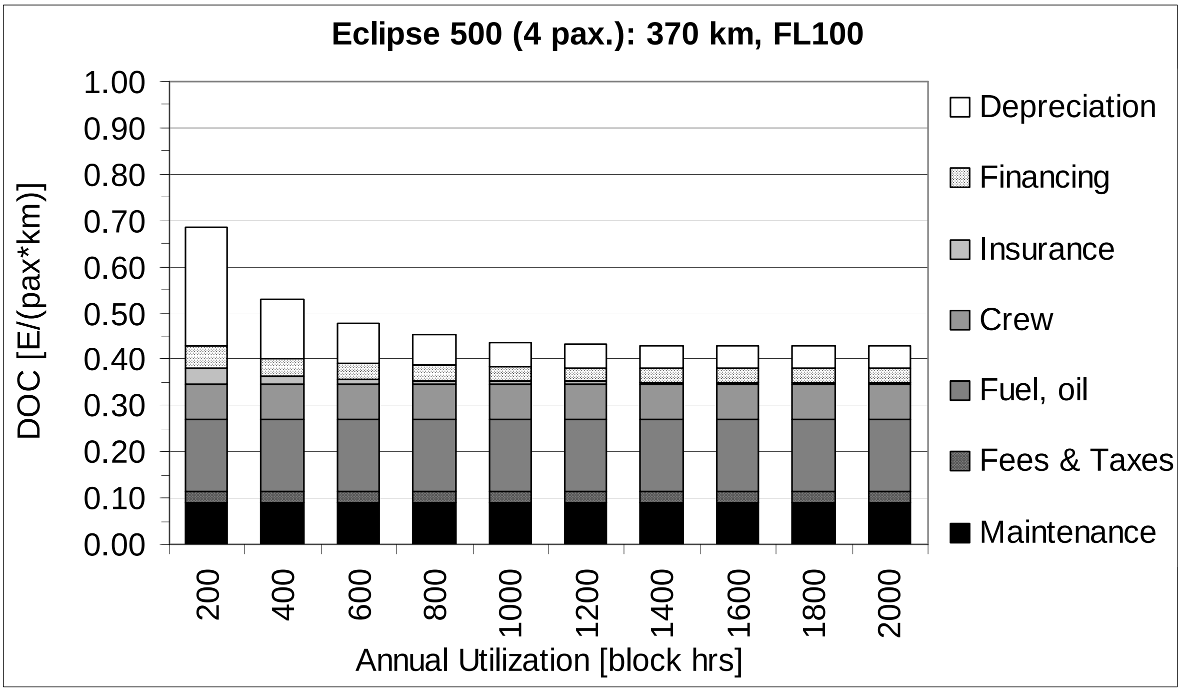


Fig.6. 70 DOC as function of annual utilization level for Eclipse 500

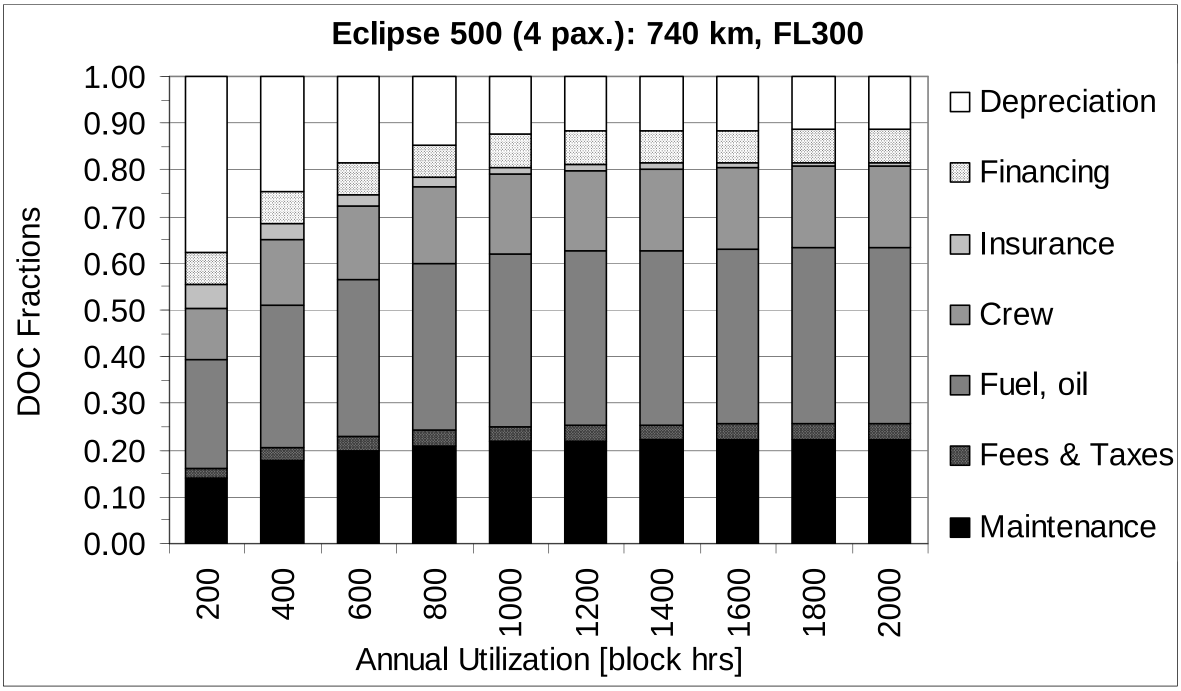


Fig.6. 71 DOC structure as function of annual utilization level for Eclipse 500

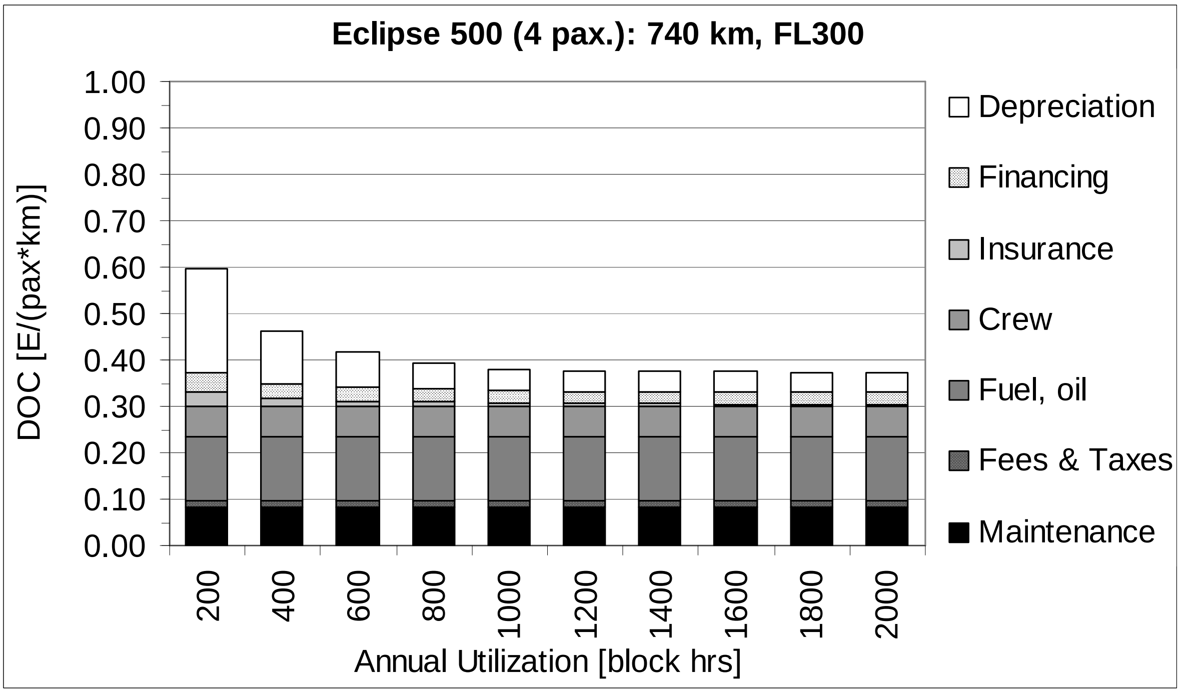


Fig.6. 72 DOC as function of annual utilization level for Eclipse 500

- Grob SPn

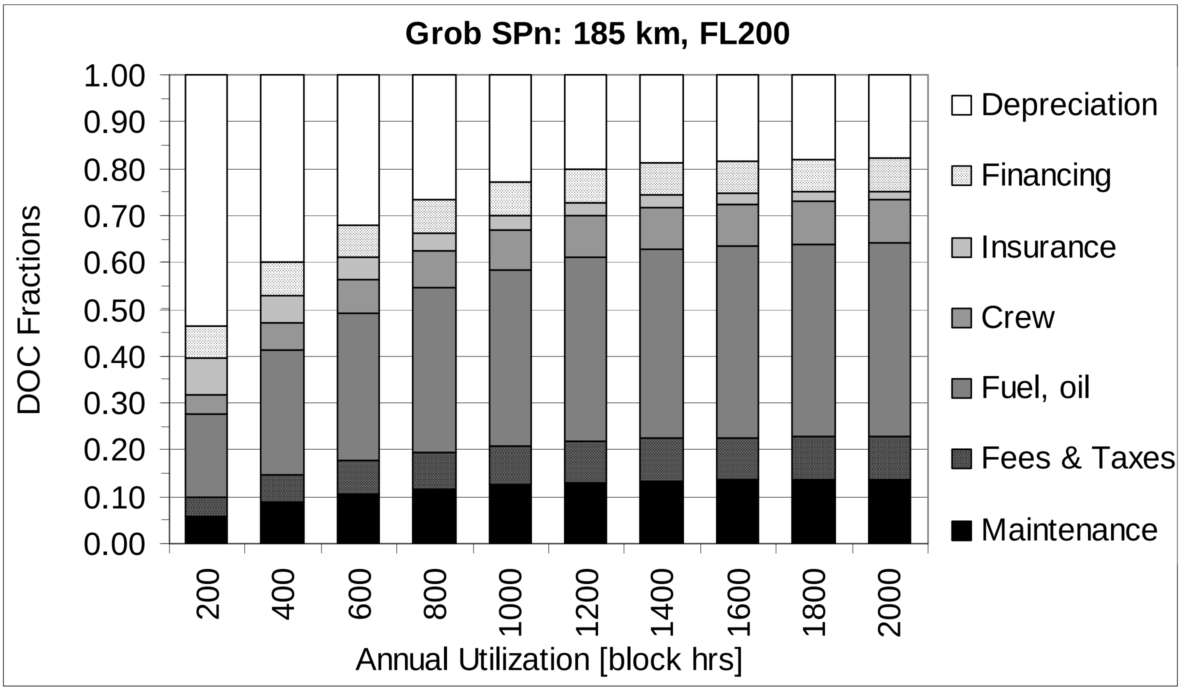


Fig.6. 73 DOC structure as function of annual utilization level for Grob SPn

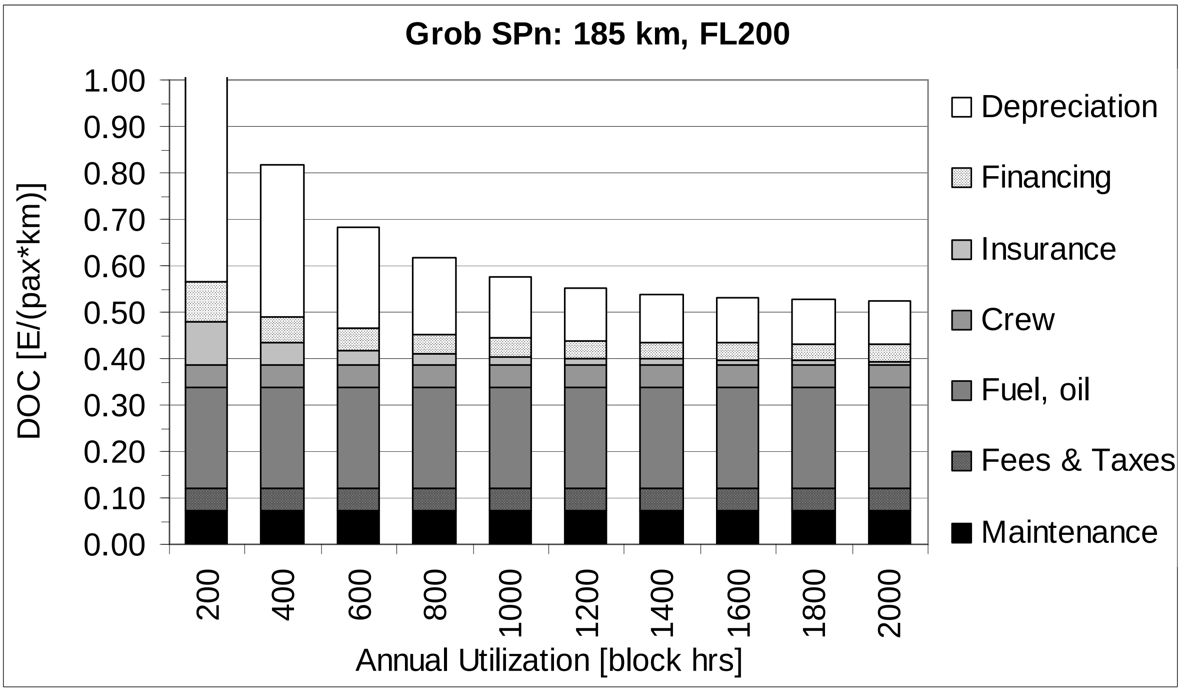


Fig.6. 74 DOC as function of annual utilization level for Grob SPn

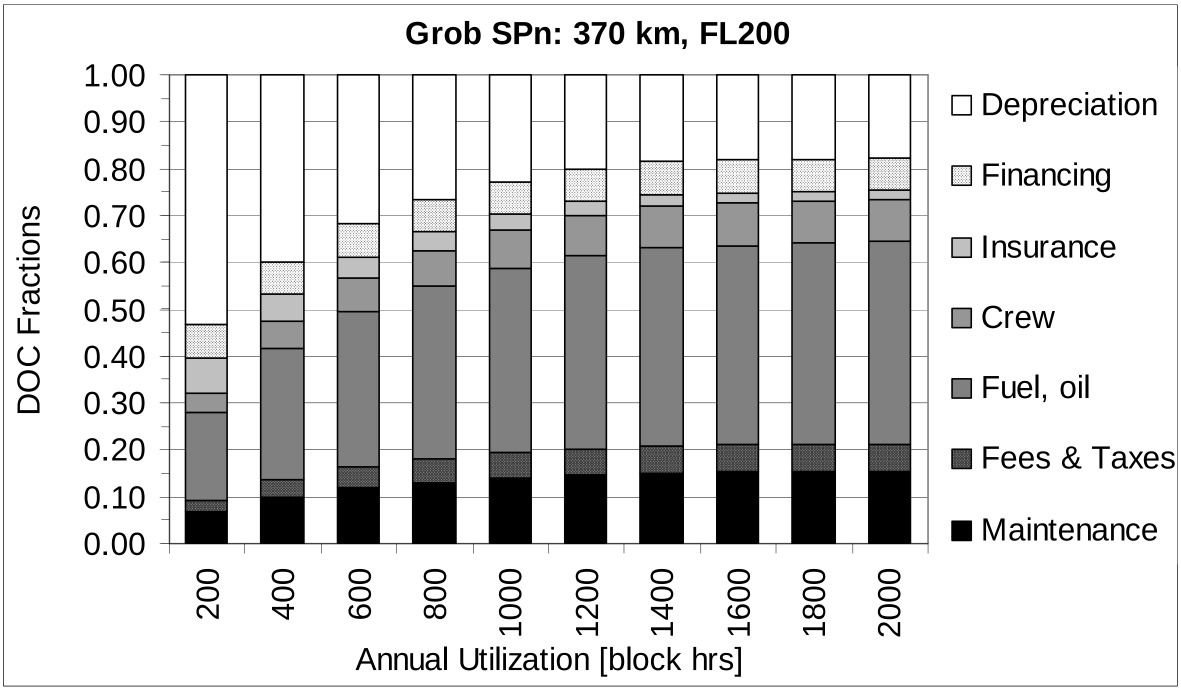


Fig.6. 75 DOC structure as function of annual utilization level for Grob SPn

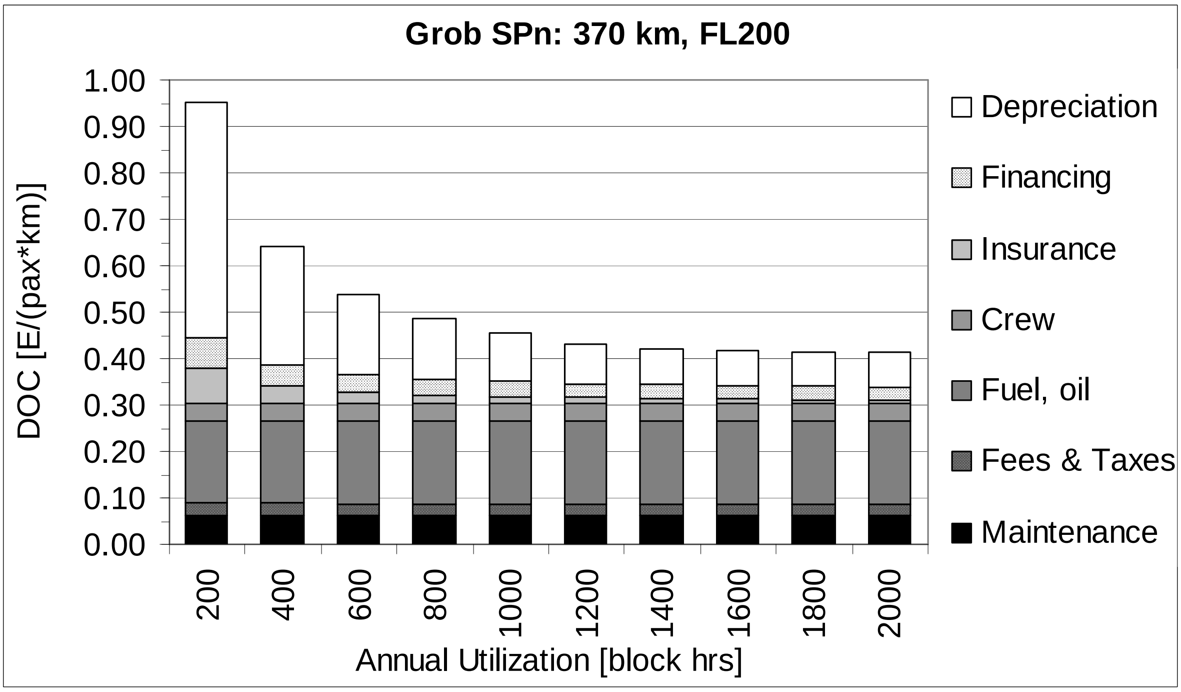


Fig.6. 76 DOC as function of annual utilization level for Grob SPn

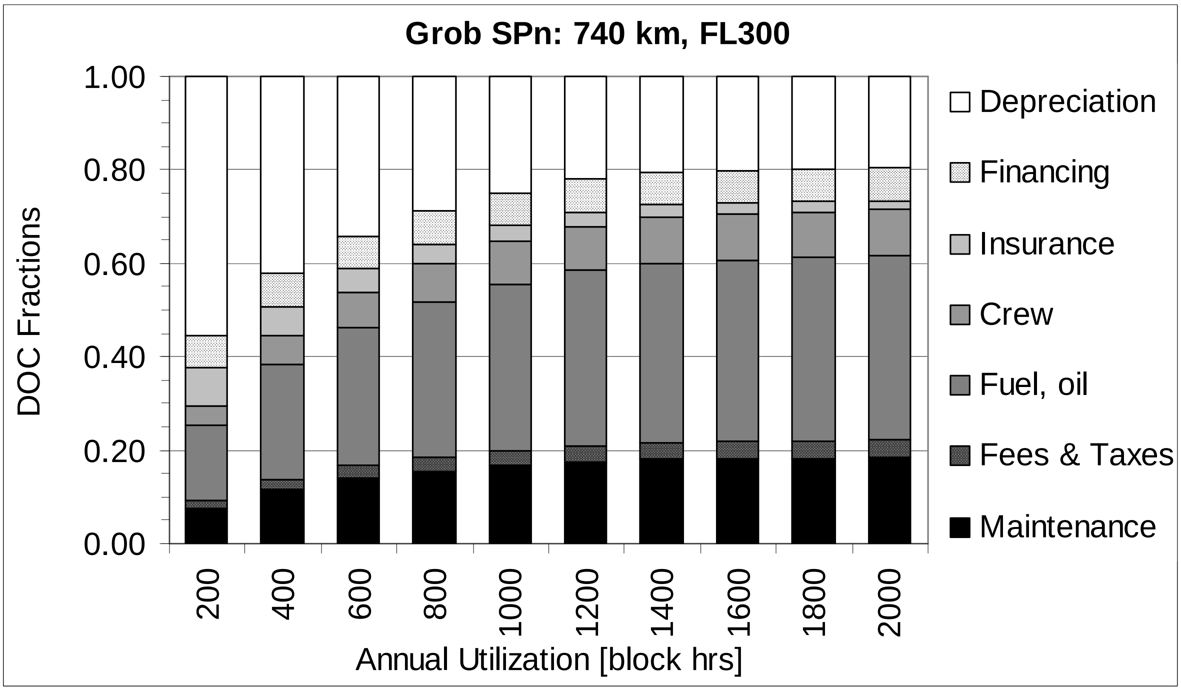


Fig.6. 77 DOC structure as function of annual utilization level for Grob SPn

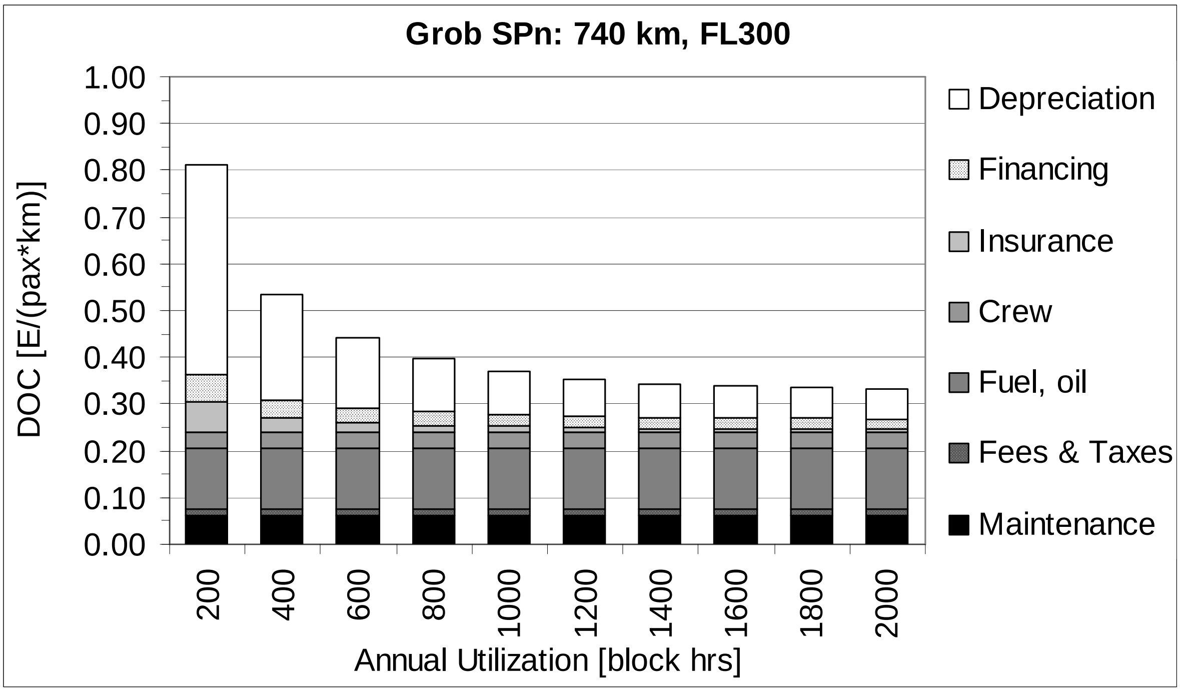


Fig.6. 78 DOC as function of annual utilization level for Grob SPn

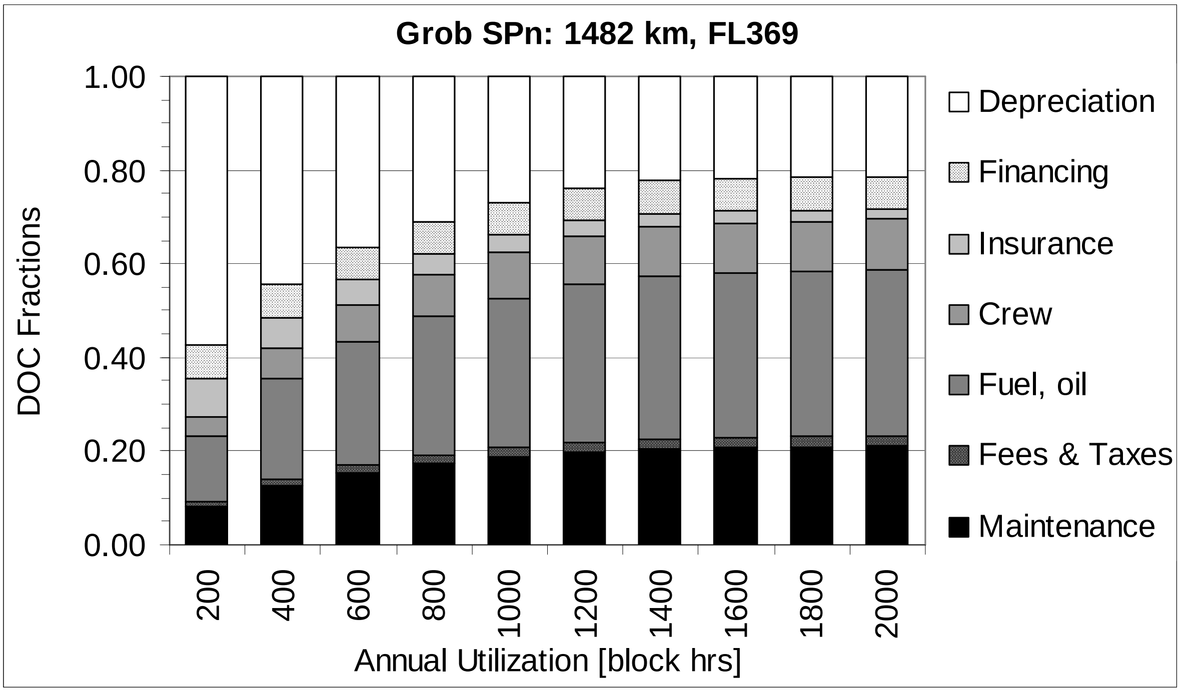


Fig.6. 79 DOC structure as function of annual utilization level for Grob SPn

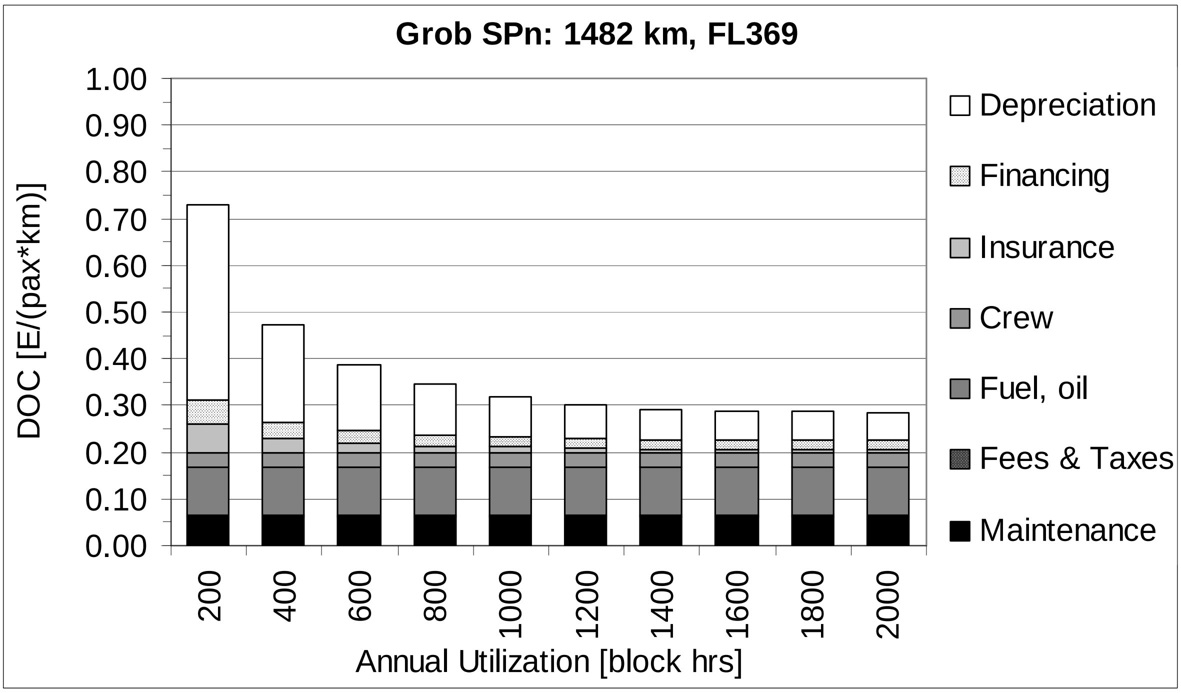


Fig.6. 80 DOC as function of annual utilization level for Grob SPn

7 AIRCRAFT EVALUATION

7.1 EVALUATION INDEXES - DEFINITIONS

Evaluation index is a an attempt to describe an airplane “value” by one number. Such synthesis causes that it should be treated carefully. There are several evaluation indexes we used:

7.1.1 Traditional Value Index (TVI)

$$TVI = \frac{V_{cruise.max} \cdot Range \cdot Vol_{cabin}}{TOFL}$$

7.1.2 Traditional Value Index including Airplane Price (TVI-P)

$$TVI - P = \frac{Range \cdot Speed_{cruise.max} \cdot Vol_{cabin}}{TOFL \cdot Price_{airplane}}$$

where:

- Range - range
- $Speed_{cruise.max}$ - maximum cruise speed
- Vol_{cabin} - cabin volume
- TOFL - takeoff field lenght
- $Price_{airplane}$ - airplane price

7.1.3 Customer Choice Index (CCI)

TVI strongly depends on aircraft size and cost that make comparisions hard to do. TVI-P is free from this disadvantage, however in our opinion both mentioned evaluation indexes are usefull for manufacturers rather than operators and customers.

Our goal is to create future EPATS aircraft requirements. The key question is: what do the customers want? To know the answer it is necessary to initiate survey concerning whole Europe. However it could cost milions and take years. Lacking such data we decided to create new valuation index – Customer Choice Index (CCI). In our opinion, there are three primary factors that customers take into account while choosing a transport type. How fast? How comfortable? And how much does it cost? Block speed is responsible for travel time, cabin volume per passenger seat shows comfort and Direct Operating Cost per pax.km answers how much does it cost. Different customers groups have different needs shown in table 7.1 below.

$$CCI = \frac{V_{.block}{}^{A} \cdot Vol_{.cab\_pax}{}^{B}}{DOC_{.pax\_km}{}^{C}}$$

	EXPONENT VALUE		
	A	**B**	**C**
CCI TYPE	Block Speed (V_{block}) [km/h]	Cabin Volume per Passenger (Vol_{cab_pax}) [m^3/pax]	Direct Operating Cost per km*pax (DOC_{km_pax}) [€/(pax*km)]
BUSINESS (CCI-BS)	2	1.41	1
NEUTRAL (CCI-N)	1	1	1
LOW COST (CCI-LC)	1	1.41	2

Tab.7. 1 CCI exponent value.

7.1.4 Passenger Kilometer Potential (Pax_{km})

Passenger kilometers (Pax_{km}) potential is important for operators. It let them choose proper both airplane type and its number, depend on passenger flow.

$$Pax_{km} = U_{ann.bl.hrs} \cdot V_{block} \cdot N_{pax}$$

where:

- $U_{ann.bl.hrs}$ - annual utilization in block hours
- V_{block} - block distance/block time
- Block Distance - origin-destination distance in straight line
- Block Time - total trip time, including all mission segments, e.g. : taxi, TO, climb, cruise, descent, landing, taxi back, etc.
- N_{pax} - Number of Passenger Seats

7.1.5 Profit Potential

This is a next important parameter for operators. It demonstrates potential profit of using particular aircraft.

$$Profit_{Potential} = U_{ann.bl.hrs} \cdot \left(V_{block} \cdot N_{pax} \cdot \eta_{pax}\right) \cdot \left(\frac{DOC_{km.pax} + IOC_{km.pax}}{\eta_{pax}}\right) \cdot \%Profit$$

- η_{pax} - Passenger Loading Factor
- $DOC_{km.pax}$ - Direct Operating Cost in €/(km*pax)
- $IOC_{km.pax}$ - Indirect Operating Cost in €/(km*pax)
- %Profit - Profit Rate

First part of this equation shows passenger flow, second – ticket price and third – profit rate. It could be simplified to:

$$Profit_{Potential} = U_{ann.bl.hrs} \cdot \left(V_{block} \cdot N_{pax}\right) \cdot \left(DOC_{km.pax} + IOC_{km.pax}\right) \cdot \%Profit$$

For calculation, we assumed: DOC to TOC ratio of 0.5 and profit rate 10%.

7.1.6 Energy Efficiency (ef)

Energetic efficiency was calculated using prof. Rochács' definition:

$$ef = \frac{Transport_{Work}}{Applied_{Energy}}$$

where:

$$Transport_{Work} = W_{payload} \cdot Distance$$

$$Applied_{Energy} = W_{fuel.used} \cdot Fuel_{Energy}$$

We assumed fuel energy (density):

- Gasoline: 48.3 MJ/kg (0.70769 g/cm^3)
- Jet fuel: 46.1 MJ/kg (0.80763 g/cm^3)

7.2 EVALUATION INDEXES - RESULTS

7.2.1 Traditional Value Index (TVI) - Results

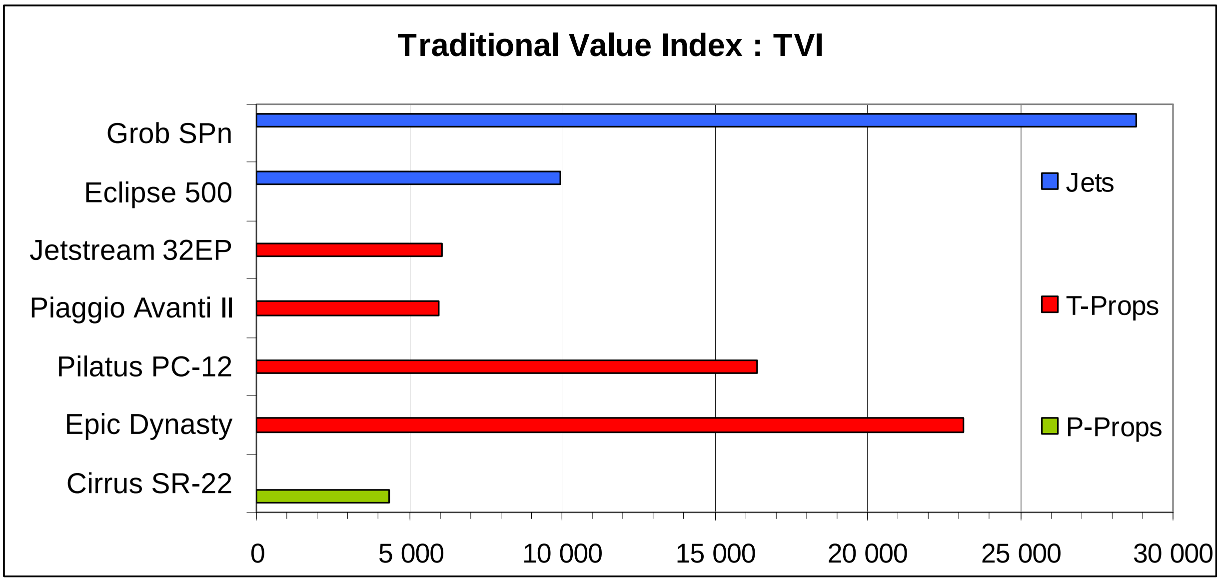


Fig.7. 1 Traditional Value Index - results

7.2.2 Traditional Value Index including airplane Price (TVI-P) - Results

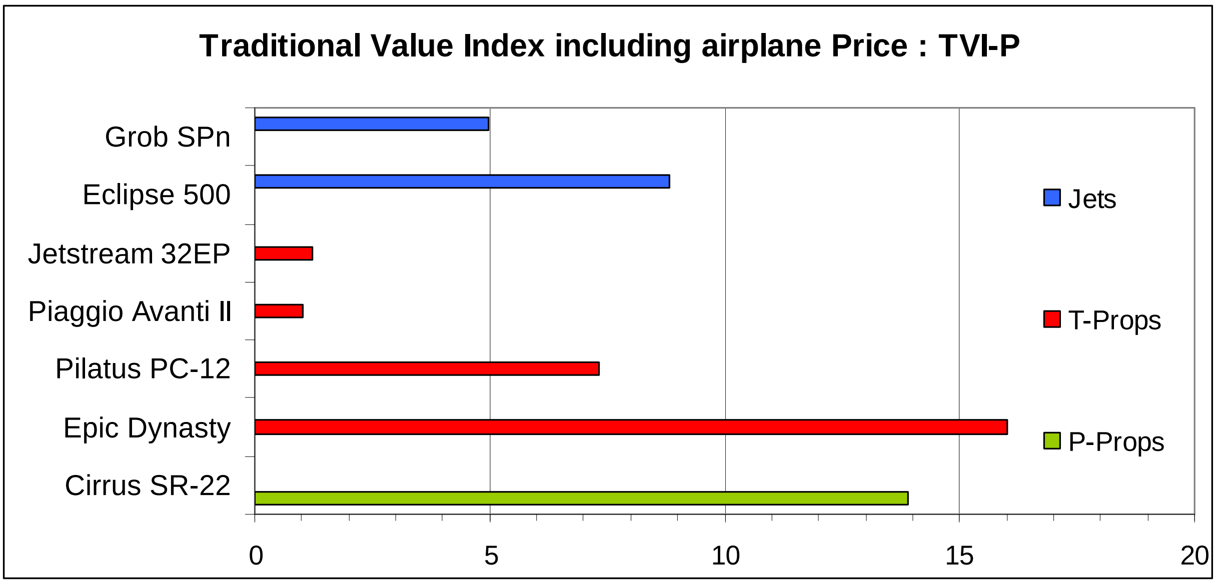


Fig.7. 2 Traditional Value Index including airplane Price - results

7.2.3 Customer Choice Index (CCI) - Results

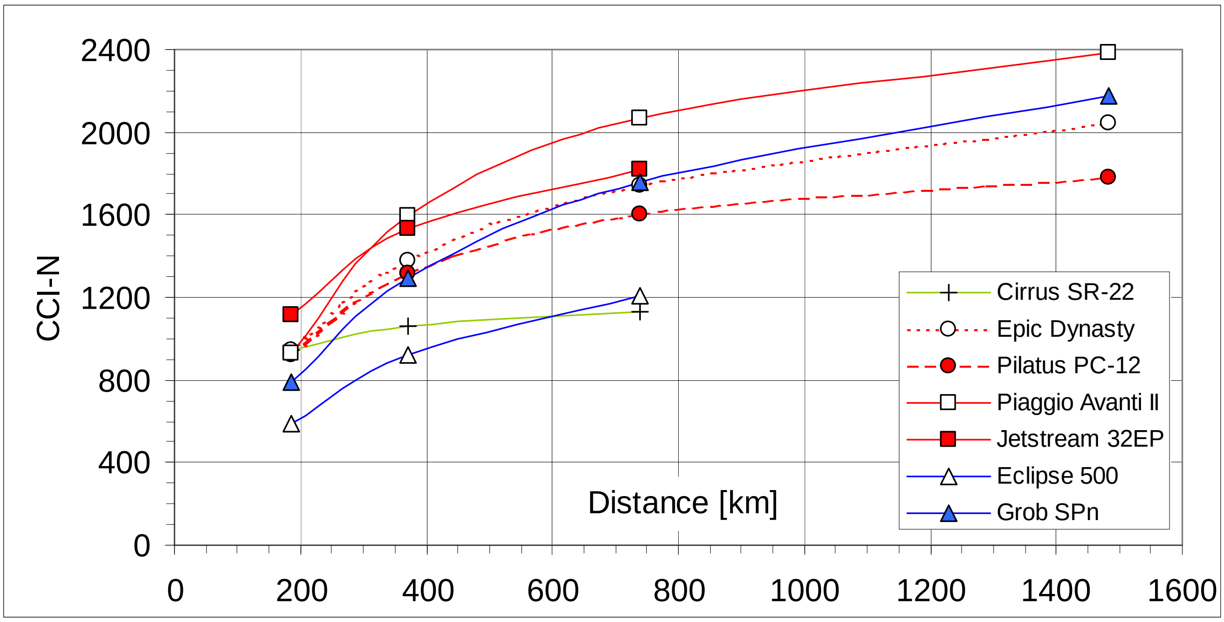


Fig.7. 3 Customer Choice Index – Neutral (CCI-N)

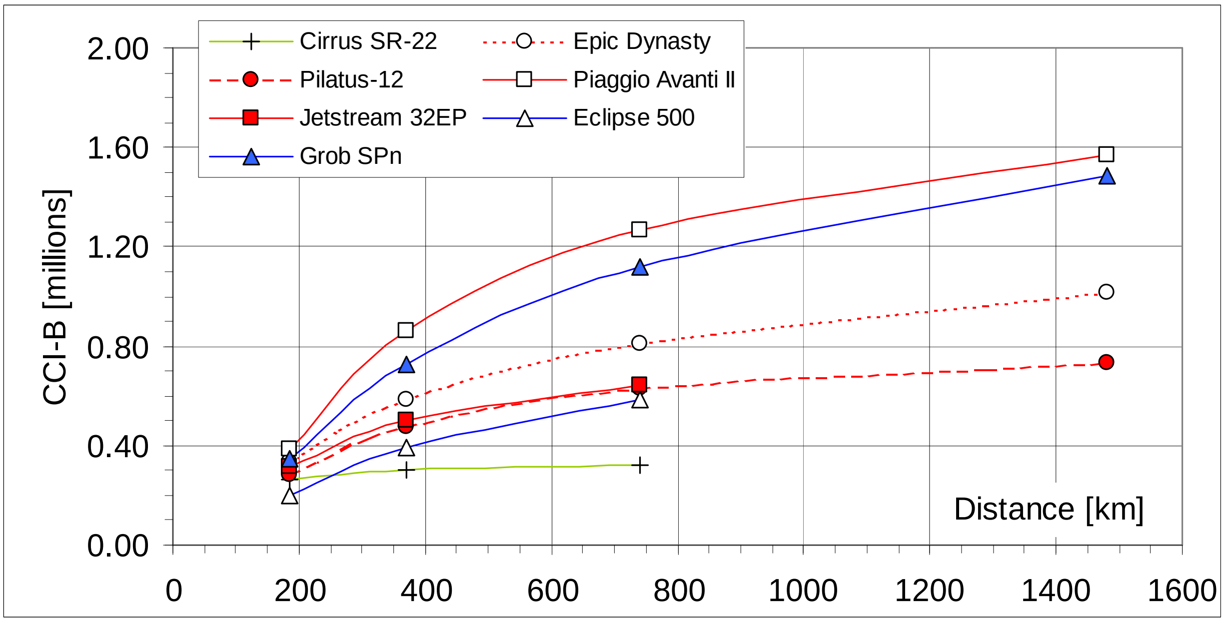


Fig.7. 4 Customer Choice Index – Business (CCI-B)

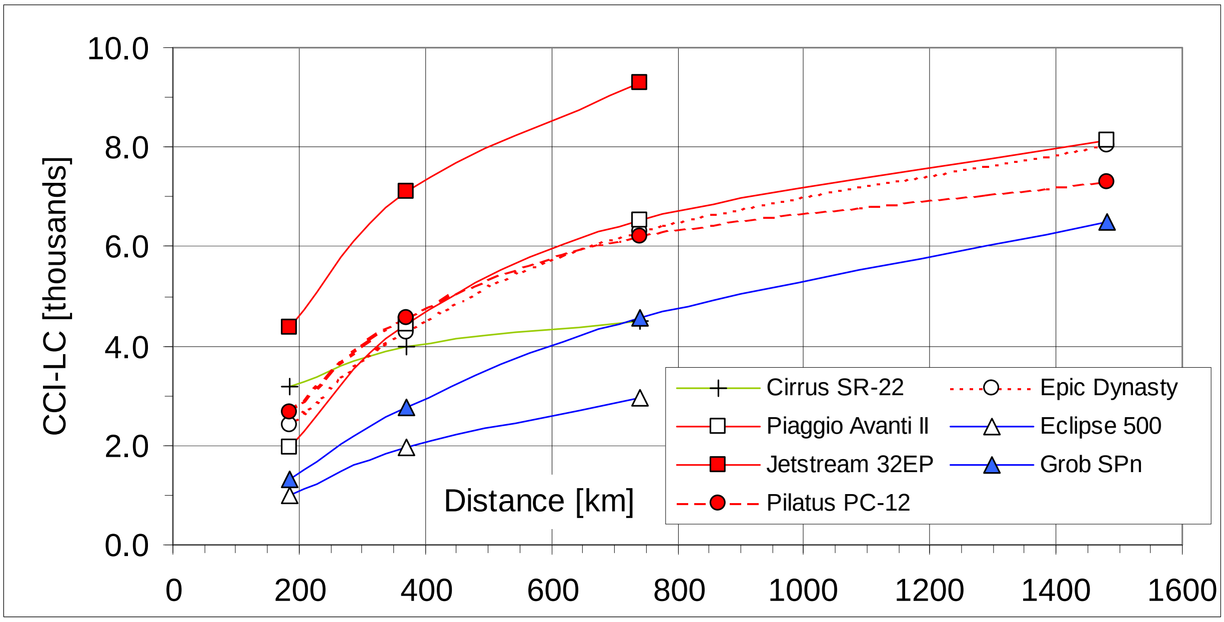


Fig.7. 5 Customer Choice Index – Low Cost (CCI-LC)

7.2.4 Passenger Kilometer Potential (Pax_{km}) - Results

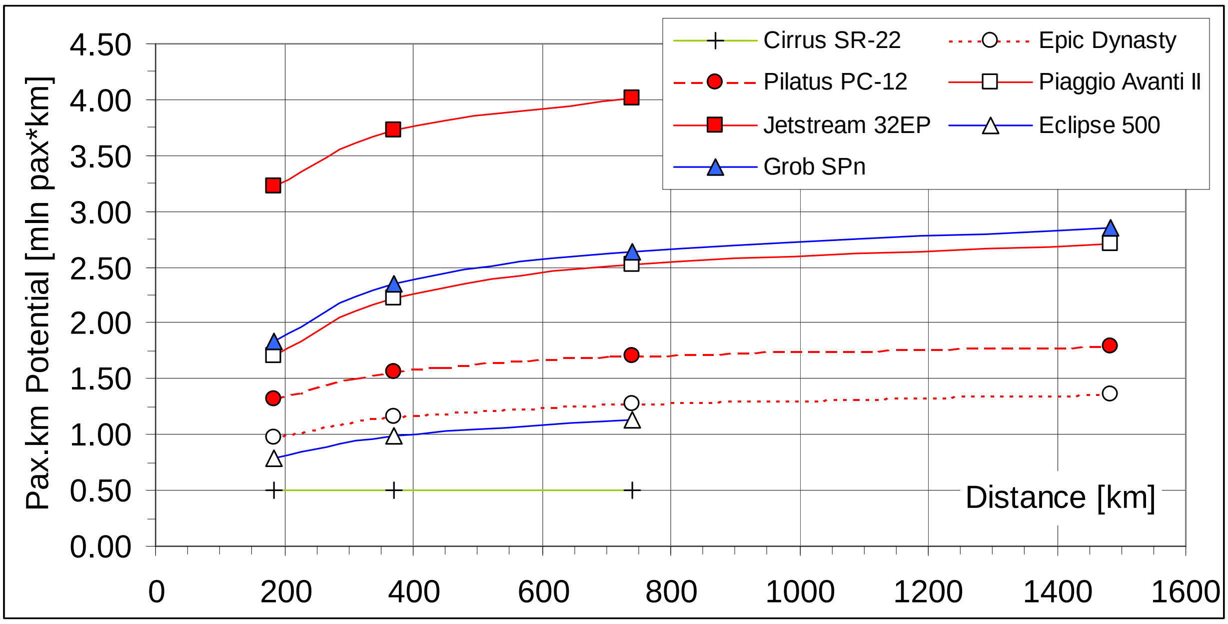


Fig.7. 6

7.2.5 Profit Potential - Results

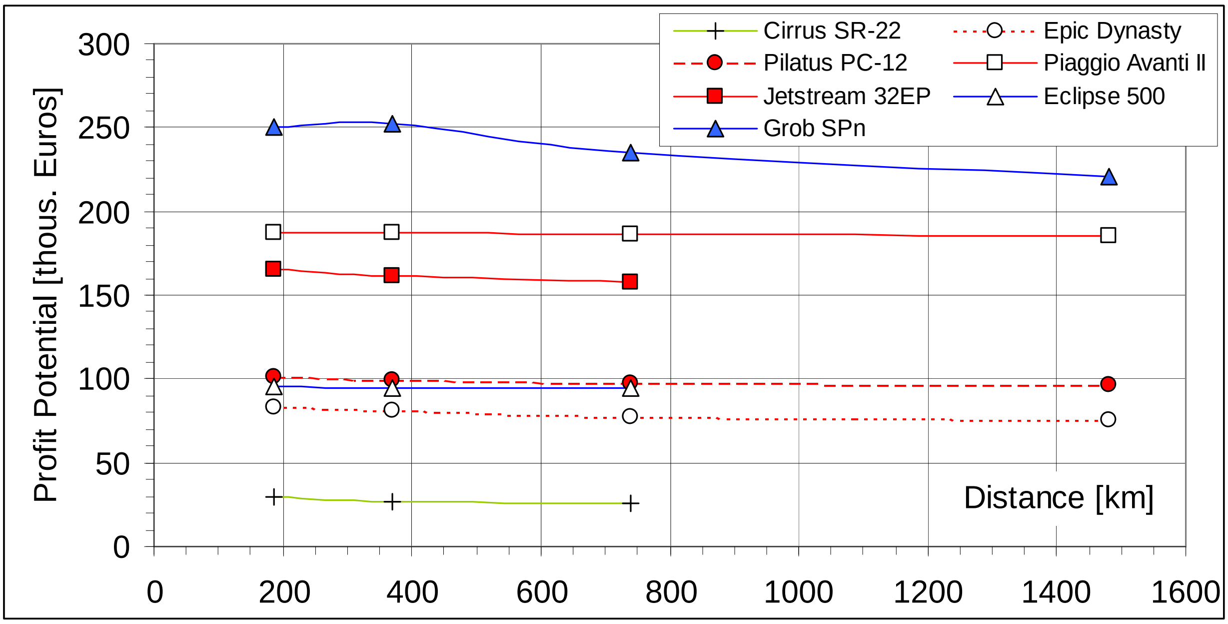


Fig.7. 7

7.2.6 Energy Efficiency (ef) by prof. Rochács definition - Results

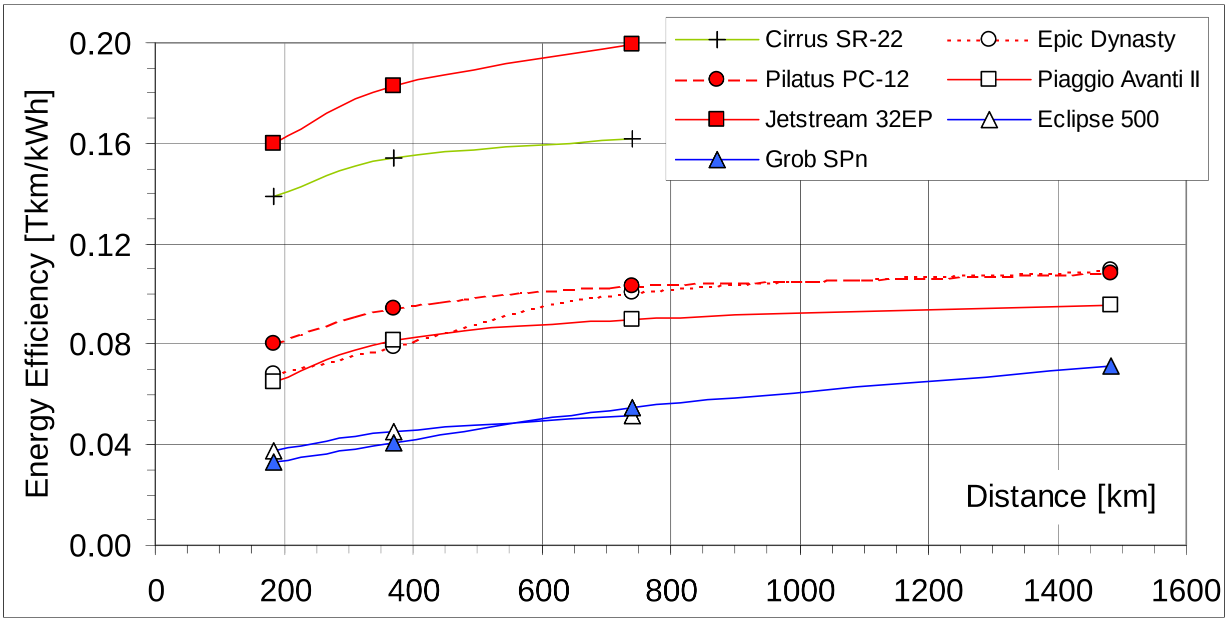


Fig.7. 8 Energy Efficiency by prof. Rochács definition

7.3 AIRCRAFT EVALUATION - SUMMARY

7.3.1 Notes

1. The assumed method of Direct Operating Cost (DOC) calculations is flexible and potentialfull. It let change all parameters: technical and economic, as well as flight parameters such as speed and altitude. The method allows to examine dependence of DOC on particular parameters.

2. The main difficulties of the analysis was lack of detailed data, both: technical and economic.

Manufacturers do not publish aerodynamics characteristics of their airplanes and characteristics of engines. Available performances are often incomplete, moreover those concern different conditions, so it is difficult to compare them.

Large economic differences across Europe cause that, in reality, there is no single, uniform "European Market", what makes calculations more difficult to do and their results more difficult to interprete.

Thus it seems clear that it is necessary to establish a European organization to collect data and process them. Ref. [2] - „Economic Values for FAA Investment and Regulatory Decision a Guide" - is a good example of what the results of such activity should be.

Detailed Indirect Operating Costs (IOC) analysis is beyond the scope of this report. This is a task for those who are familiar with economics and marketing (not for aircraft designers).

3. Setting out development directions according to imprecise analyses and/or under the influence of fashions is not a right way. Also, copying foreign (USA) trends without taking under consideration European situation (conditions) is a mistake.

7.3.2 Conclusions

There is no single particular flight condition which can be named the best. One minimizes operating cost, the other fuel consumption. Another maximizes block speed. For purpose of aircraft demand calculation (WP2), block speed to operating cost ratio is selected as a measure of merit.

Usually operating costs are expressed per hour (flight or block). In our opinion this is not a good manner. For example, let's imagine two airplanes with the same hourly costs. The flight distance is the same, too. Are the travel costs the same? We need one more piece of information to answer this question: block speed. So, the faster airplane will be cheaper per km and also more attractive for high-time-value customers. Table 7.2 contains an exemplary data. Expressing cost per km is better, simpler and more precise.

DOC [€/h]	1000	1000
V.block [km/h]	350	450
DOC [€/km]	2.86	2.22

Tab.7. 2 Comparison of two manners of DOC expression

Usually operating costs are published as single numbers. In fact (for assumed flight conditions), they are functions of two variables: distance and utilization intensity (see Fig.7.9). So, the questions is: what does that single number mean? It means nothing, unless we specify conditions. Talking about an operating cost as a one number is therefore a misunderstanding.

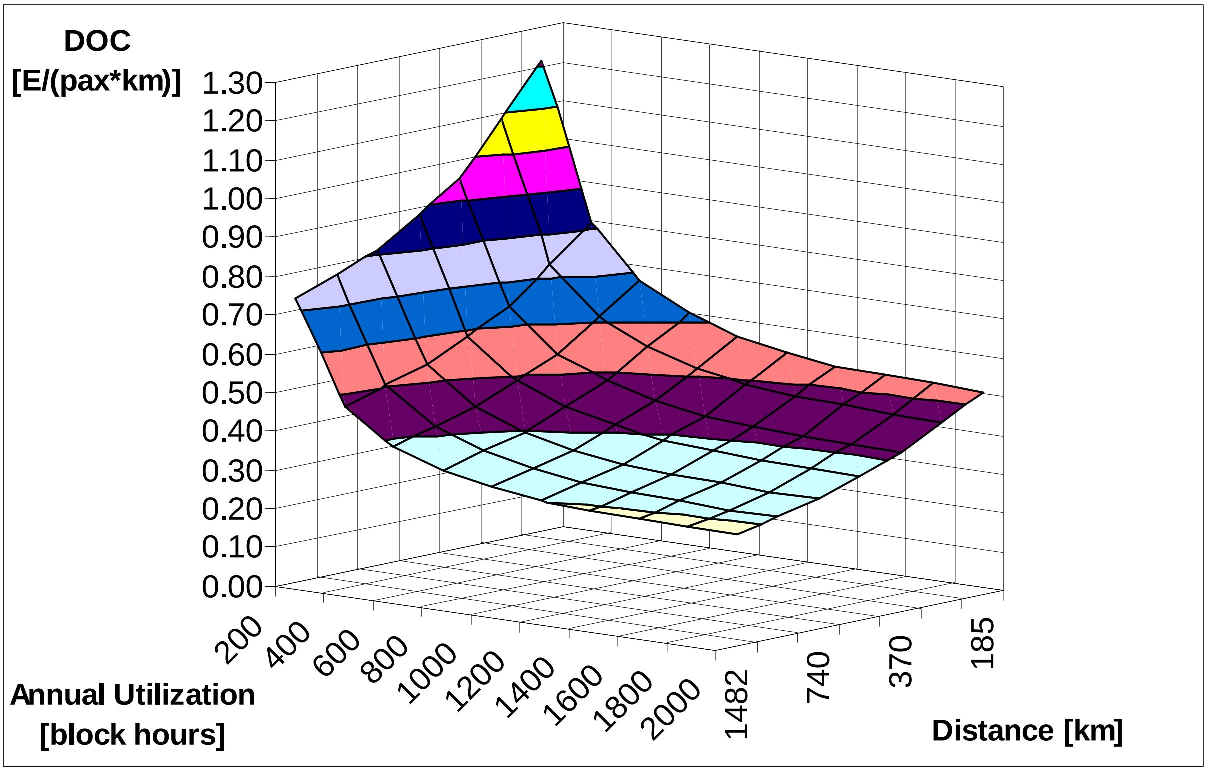
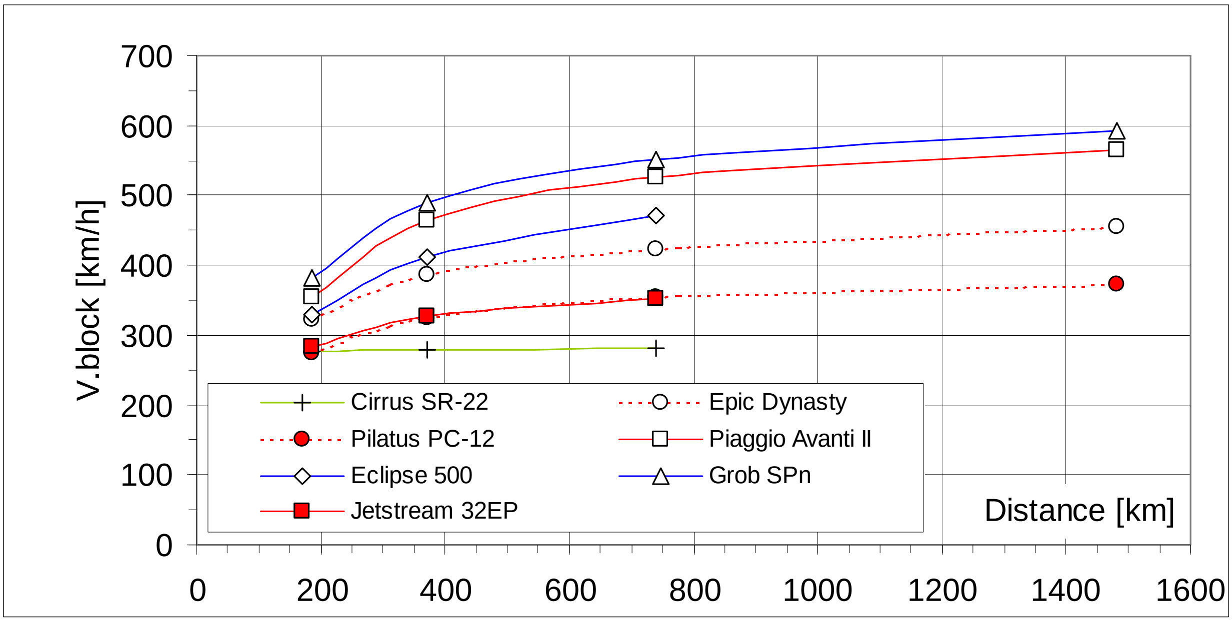


Fig.7. 9 DOC of Grob SPn as a function of distance and annual utilization

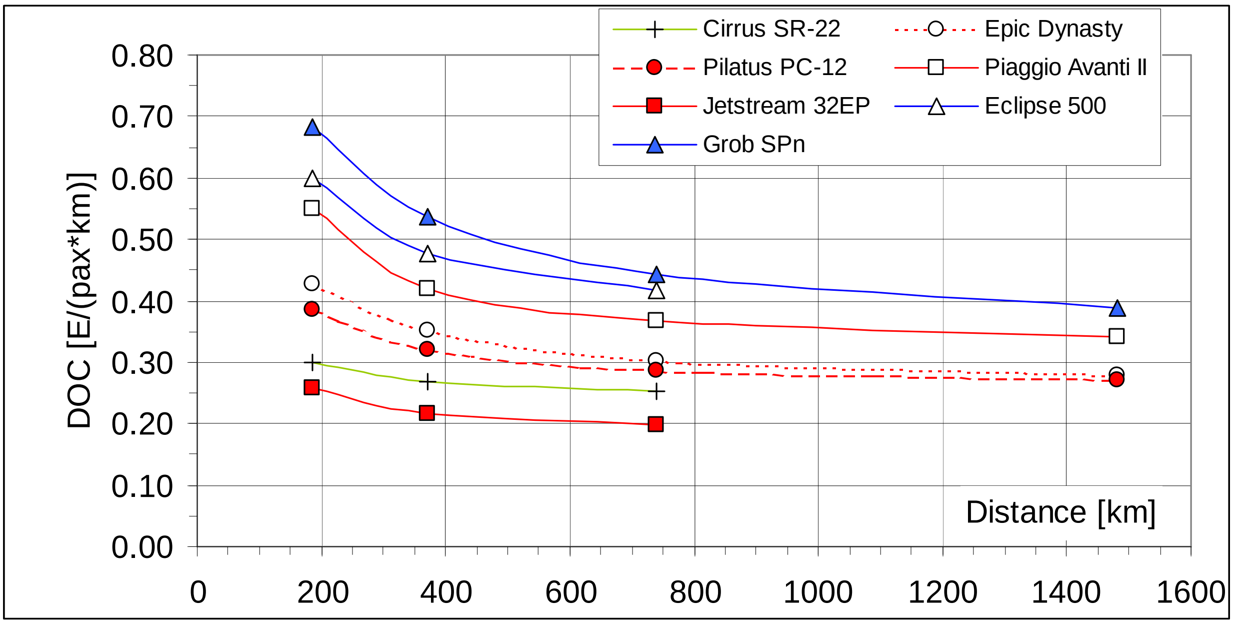
- Performed detailed analyses in fields of Operating Cost and Fuel Consumption (environmental issues) for different types of airplanes, for current utilization level of 600 block hours, show as follows:

- Block Speed (repeated Fig.6.9)



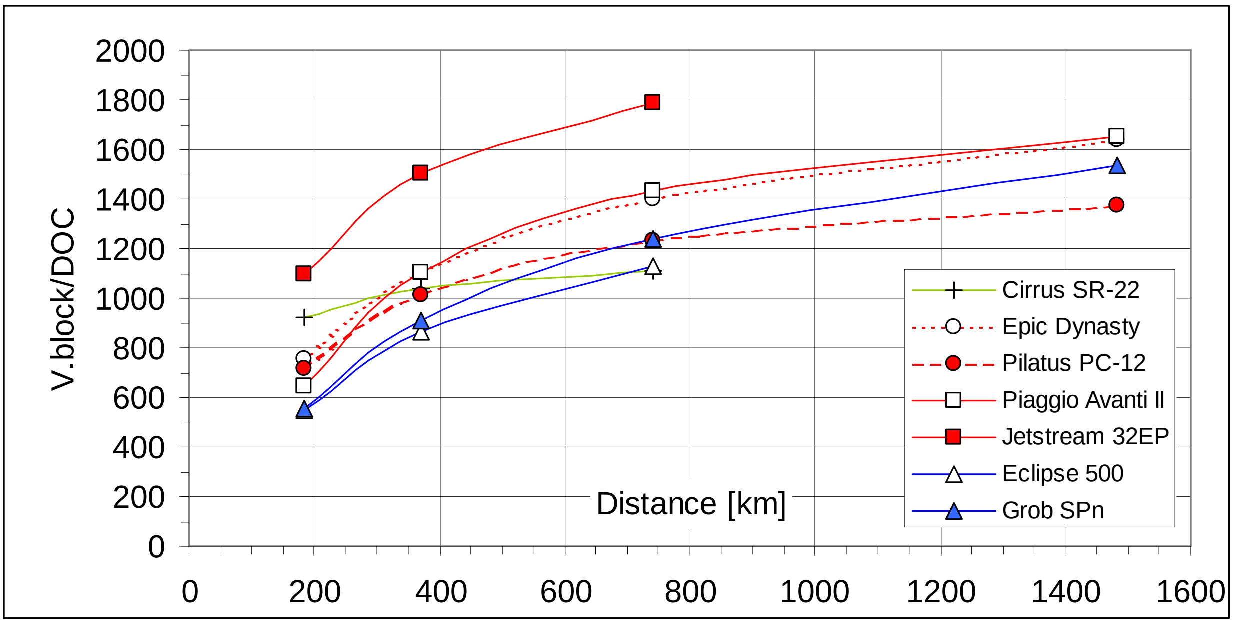
Block speed increases with distance. Jets are the fastest, however new a generation of turbo-props is just a steep behind, offering benefits in operating cost and fuel consumption. Older turbo-props offer medium speeds. Piston is the slowest, however it gains advantage at short distances. This is due to the fact that it flies at low altitudes and spend less time climbing.

- DOC (repeated Fig.6.10)



DOC decreases with distance. Jets are the most expensive of all. Medium size turbo-props (up to 9 pax.) offer costs at medium level. Piston is the cheapest, except large turbo-prop (19 pax.) which is beyond the competition.

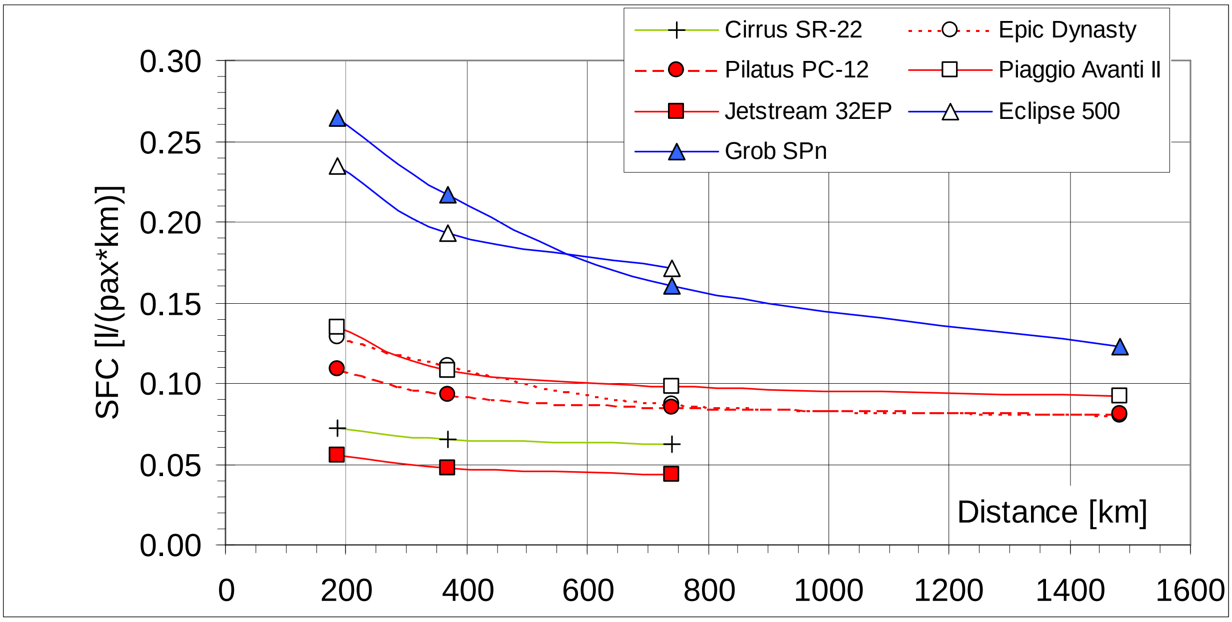
- Block Speed to DOC ratio (repeated Fig.6.12)



Block speed to DOC ratio increases with distance. In general, jets are the worst, but when distance increases they become more competetive, winning with piston and slow medium size (9 pax.) turbo-prop (t-prop). Fast medium size (9 pax.) t-props are good at all distances except short, where small piston dominates. Jetstream, 19 pax. t-prop is the best of all at any distance.

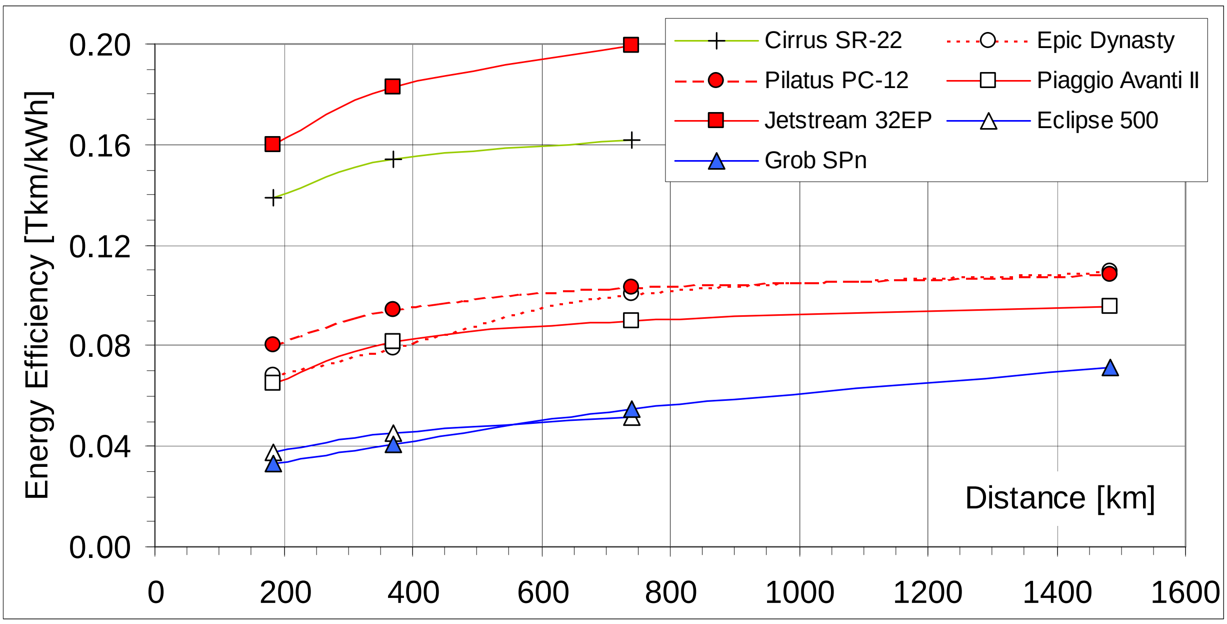
Block speed to DOC ratio is a significant parameter used for airplane demand calculation. However there are other factors customers take under account while choosing a transport type. Safety and comfort are important and comfort does not mean, cabin volume and seat pitch only. It is also connected with noise and vibration levels and something called "ride quality". This report contains an attempt to consider part of these additional requirements (cabin volume per passenger seat, only) - Customer Choice Index. Further analyses are needed to take under account the rest.

- SFC (repeated Fig.6.11)



SFC decreases with distance. Jets have the highest fuel consumption. Normal category (up tp 9 pax.) turbo-props have medium, while piston the lowest (fuel consumption). Commuter category turbo-prop – Jetstream (19 pax.) is beyond the competition again.

- Energy Efficiency (repeated Fig.7.8)



Energy efficiency increases with distance. Jets are the least effective of all, turbo-props are medium and piston is high efficient. Once again, large turbo-prop Jetstream (19 pax.) is the best, offering the highest energy efficiency.

7.3.3 Total Operating Cost (TOC)

Total Operating Cost (TOC) consist of two components: DOC and IOC.A detailed IOC analysis is beyond the scope of this report, as mentioned ealier. Current IOC fraction was estimated on the basis of the available data. Our vision of IOC fraction reduction and increasing annual utilization till 2020 is shown on Fig.7.10.

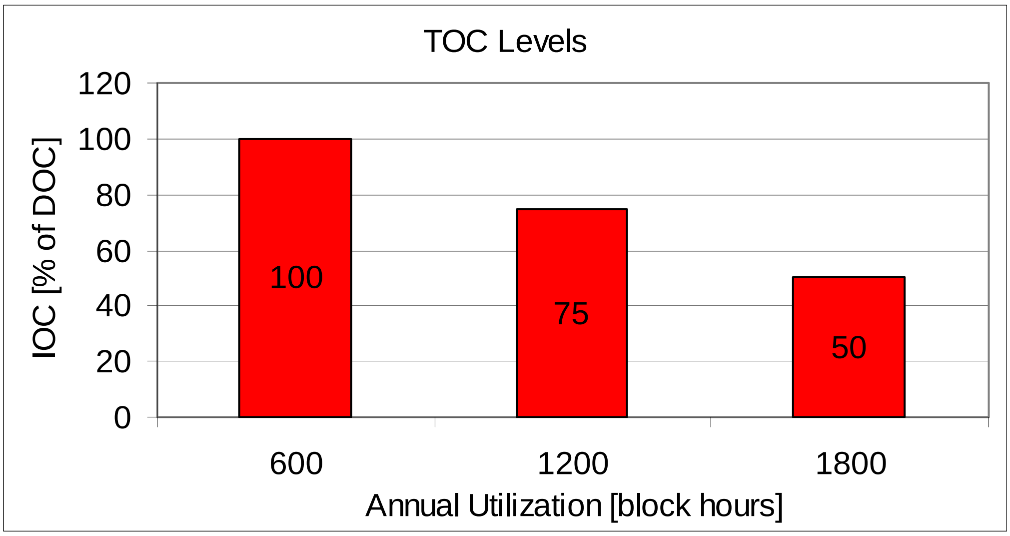


Fig.7. 10 Vision of IOC fraction reduction till 2020.

Now we will examine the potential of TOC reduction. In the first case, the current IOC fraction is assumed and onle DOC reduction (due to increased utilization level) influences TOC. Figure 7.11 shows the results. The “low” reduction presents the Cirrus SR-22 value, while the highest - Piaggio. In the second case, both DOC and IOC decrease. It can be seen on Fig 7.12 that reductions are much greater. So, it is clear, IOC decline is also very important.

Further TOC reduction is possible, however requires designing new construction. Of course: increasing utilization intensity, IOC decreasing and introduction of new aircraft into service together, could bring the best results.

In reality TOC reduction may be even more significant. The reason is that, today’s small operators with their small fleets and low utilization levels could be far away from operational and maintenance optimum (as it is assumed in this analysis), which results in higher prices.

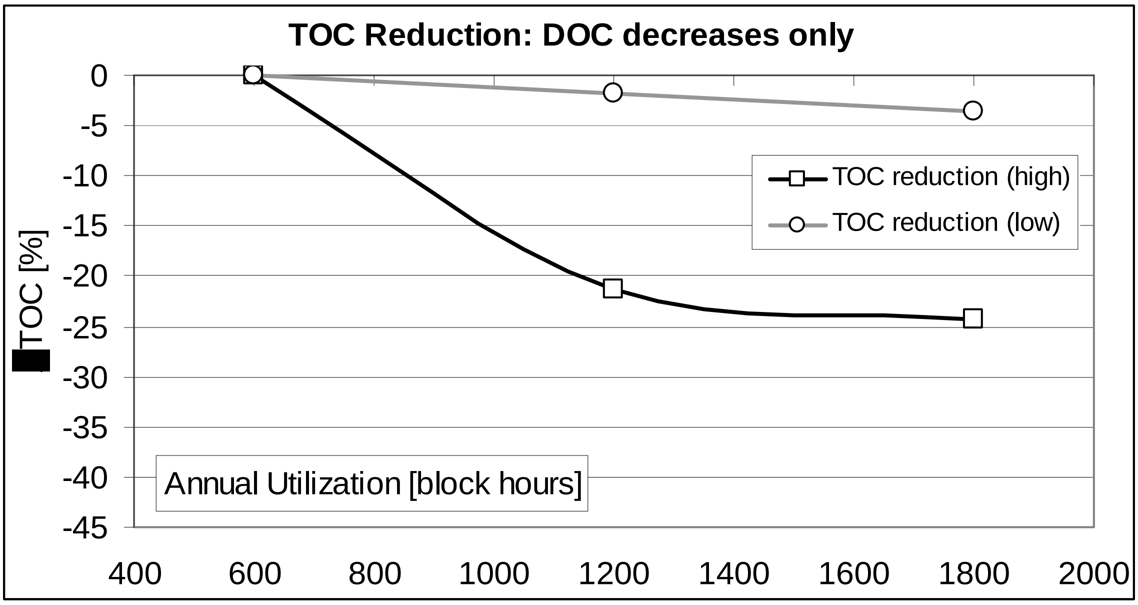


Fig.7. 11 TOC reduction potential (DOC is changing only)

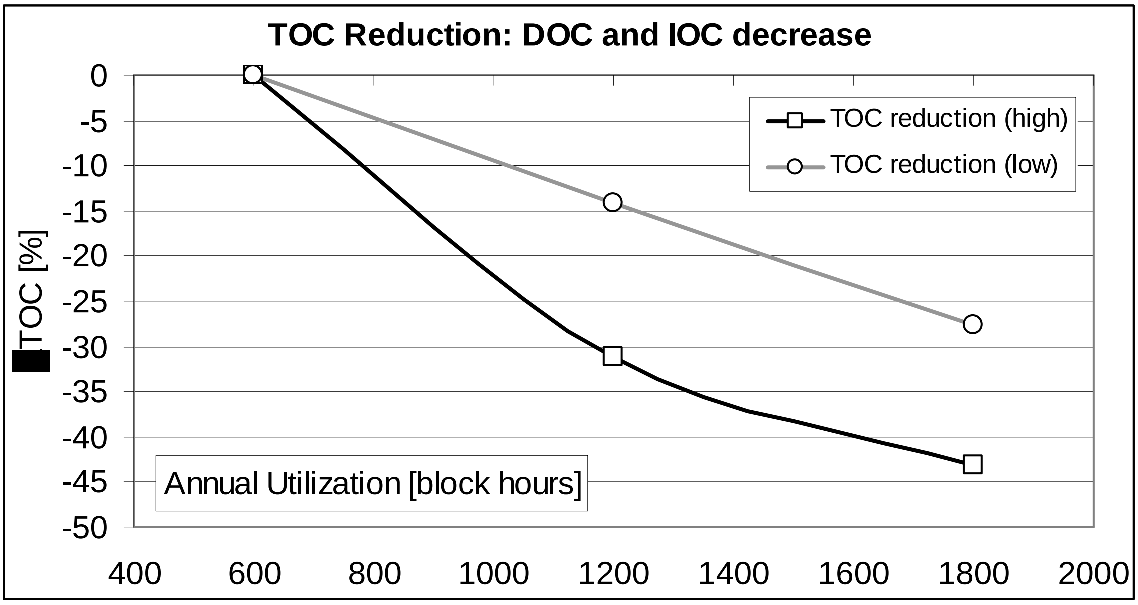


Fig.7. 12 TOC reduction potential (both: DOC and IOC are changing)

7.3.4 Vison

In our opinion the General Aviation in Europe is at the point where traditional airlines were before cheap operators era. Please notice, they did not use any new revolutionary airplanes. They optimized utilization of current fleet. This reduced operating cost and increased accessibility of air transport. Similar way (together with new generation of aircraft) wolud be the future of European GA if we had to fulfill the EPATS goals till 2020.

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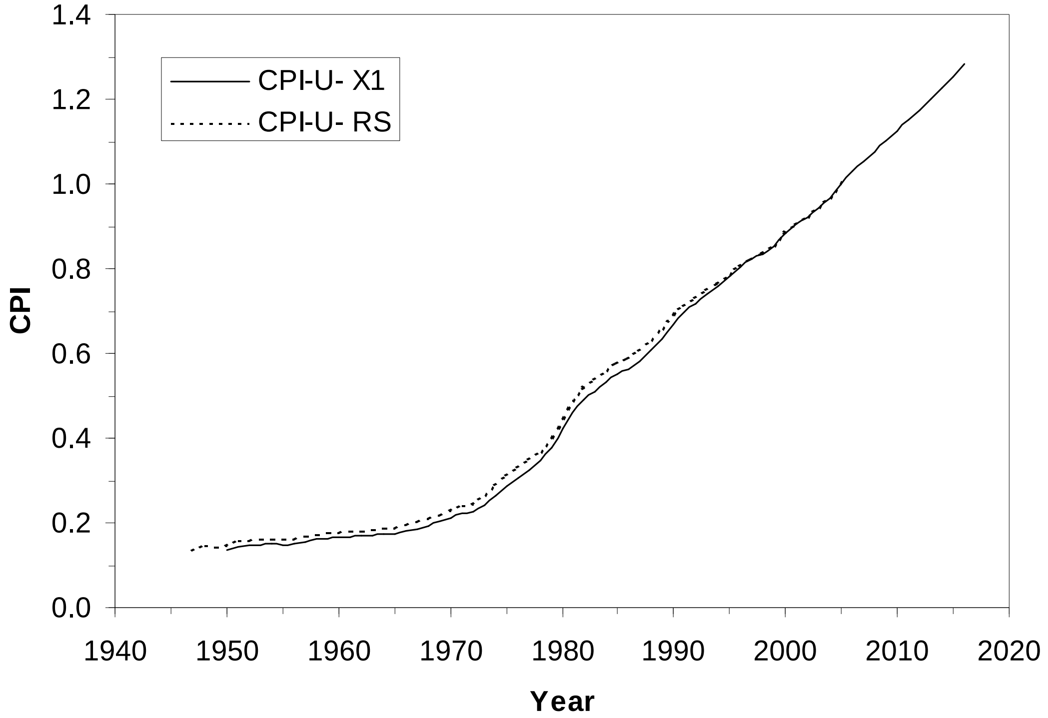
[14]. "EUROCONTROL Trends in Air Traffic, volume 1: Getting to the Point: Business Aviation in Europe" Eurocontrol

[15]. Institute of Aviation, BP1-ILot : "Airplane Data Base" – EPATS T1.1

APPENDIXES

I COST ESCALATION FACTORS - CONSUMER PRICE INDEX

Based on Ref.[4]



Year	CF RS	CF X1	Year	CF RS	CF X1	Year	CF RS	CF X1	Year	CF RS	CF X1
1947	0.135		1965	0.190	0.175	1983	0.538	0.510	2001	0.906	0.907
1948	0.146		1966	0.196	0.180	1984	0.559	0.532	2002	0.921	0.921
1949	0.144		1967	0.202	0.186	1985	0.578	0.551	2003	0.942	0.942
1950	0.146	0.134	1968	0.210	0.193	1986	0.588	0.561	2004	0.967	0.967
1951	0.157	0.145	1969	0.219	0.202	1987	0.608	0.582	2005	1.000	1.000
1952	0.160	0.147	1970	0.230	0.211	1988	0.630	0.606	2006		1.032
1953	0.161	0.148	1971	0.240	0.221	1989	0.658	0.635	2007		1.054
1954	0.162	0.150	1972	0.247	0.227	1990	0.690	0.669	2008		1.077
1955	0.162	0.149	1973	0.263	0.242	1991	0.715	0.697	2009		1.101
1956	0.164	0.152	1974	0.289	0.266	1992	0.733	0.718	2010		1.125
1957	0.170	0.156	1975	0.313	0.288	1993	0.751	0.740	2011		1.150
1958	0.175	0.161	1976	0.331	0.304	1994	0.767	0.759	2012		1.175
1959	0.176	0.162	1977	0.352	0.324	1995	0.786	0.780	2013		1.201
1960	0.179	0.165	1978	0.367	0.346	1996	0.807	0.803	2014		1.227
1961	0.181	0.166	1979	0.401	0.379	1997	0.824	0.822	2015		1.254
1962	0.182	0.168	1980	0.445	0.421	1998	0.836	0.835	2016		1.282
1963	0.185	0.171	1981	0.487	0.461	1999	0.853	0.853			
1964	0.187	0.173	1982	0.516	0.490	2000	0.882	0.882			

II CREW and MECHANICS SALARIES

Based on Ref. [2].

	Economic Value Category	Avr. Crew Cost * [$/hr]	Pilot Direct [$/hr]	Pilots Benefits [$/hr]	Co-Pilot Direct [$/hr]	Co-Pilot Benefits [$/hr]	Avr.Crew Salary **	Pilots Salary	Co-Pilot Salary	Training Cost ***
1	Piston Engine Airplanes 1 to 3 seats (<=200hp)	45					*38 250*			
2	Piston Engine Airplanes 1 to 3 seats (>200hp)	45					*38 250*			
3	Piston Engine Airplanes 4 to 9 seats One-Engine (<=200hp)	45					*38 250*			
4	Piston Engine Airplanes 4 to 9 Seats One-Engine (>200hp)	45					*38 250*			
5	Piston Engine Airplanes 4 to 9 Seats Multi-Engine	45					*38 250*			
6	Piston Engine Airplanes 10 or more Seats	112	90	22			39 872	39 872		4 400
7	Turboprop Airplanes 1 to 9 seats One-Engine	181	139	42			64 436	64 436		4 537
8	Turboprop Airplanes 1 to 9 seats Multi-Engine	238	183	55			84 728	84 728		6 190
9	Turboprop Airplanes 10 to 19 seats	244	183	55	163	49	86 864	84 728	75 472	8 572
10	Turboprop Airplanes 20 or more seats	433	211	63	163	49	154 148	97 544	75 472	11 706
11	Turbojet/Turbofan Airplanes <=12,500 lbs	475	214	64	158	47	169 100	98 968	72 980	10 250
12	Turbojet/Turbofan Airplanes >12,500 lbs and <=65,000 lbs	559	251	75	185	56	199 004	116 056	85 796	13 695
13	Turbojet/Turbofan Airplanes >65,000 lbs	713	315	95	229	69	253 828	145 960	106 088	24 401
14	Rotorcraft Piston <=6,000 lbs	45					38 250			
15	Rotorcraft Turbine <=6,000 lbs	188					66 928			
16	Rotorcraft Piston >6,000 lbs	NR					NR			
17	Rotorcraft Turbine >6,000 lbs	233					82 948			
18	Other									

* Crew: for GRA groups 1-5 and 16 crew cost=value of time=45 $/hr ; for other categories, crew cost includes salaries and benefits reported by and assumed 356 flight hours (based on 2002 NBAA salary survey, p.136)Conclin and deDeccker

** For categories 1-5 and 16 assumed 850 flight hours per year. For rest 356 hours.

*** Per 1 crew member.

	Salary* [$]	Cost per Hour	Year	Source
Flight Attendant				
Air Carrier (Scheduled)	51 120	32	2002	BLS National Compensation Survey
Corporate (Unscheduled)	47 160	29	2002	NBAA Compensation & Benchmark Survey
Air Trafic Controller				
Federal	92 000	58	2002	BLS National Compensation Survey
Contract Tower (Salary & Benefits)	55 000	34	2002	House Aviation Subcommittee Hearing
Airfield Operations Specialist	40 850	26	2002	BLS National Compensation Survey
Aircraft Maintenance and Technicians				
A&P Maintenance Technician	57 614	36	2002	NBAA Compensation & Benchmark Survey
Aviation Technician	56 238	35	2002	NBAA Compensation & Benchmark Survey
Manager of Maintenance	84 488	53	2002	NBAA Compensation & Benchmark Survey
Maintenance Foreman	72 013	45	2002	NBAA Compensation & Benchmark Survey
Maintenance Technician Helper	29 671	19	2002	NBAA Compensation & Benchmark Survey
Avionics Technician	47 900	30	2002	Aviation Today
Lead Mechanic	51 500	32	2002	Aviation Today
Line Mechanic	47 500	30	2002	Aviation Today
Maintenance Directors	64 900	41	2002	Aviation Today
Mechanics & Technicians	48 500	30	2002	Aviation Today
Mechanic's Assistant	38 000	24	2002	Aviation Today

* Assumption: 1600 annual work hours

Document Change Log:

Version	Author /Organisation	Date of Release	Description of the release	Modifications (sections affected and relevant information)
0	W. Gnarowski M. Pokorski W. Zdrojewski (IoA)	January 18, 2008	**D4.2 Operating Cost Analysis**	v2.4 Final
	W. Gnarowski M. Pokorski W. Zdrojewski (IoA)	27 June, 2008	**D4.2 Operating Cost Analysis**	v.2.5 Final Errata, page 2. Document distribution list.

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