Generating Cost Efficiency Charts

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***Abstract*- The aim of this paper is to construct with a help of a local airline a cost efficiency charts, for three given aircraft to operate in three independent sectors. These chart are generated by an Excel code, the efficiency charts would be useful for airlines and fleet planners in their decision making process.**

I. INTRODUCTION

The intent of this paper is to calculate the cost efficiency for three aircraft namely B737-500, A319, and A320 for prescribed sectors. The cost efficiency is to be calculated using the flight data provided by an airline and the output was assessed for two possible flight scenarios. The cost efficiency charts would be useful for airlines and fleet planners in the discussion making, and in-depth rout analysis. The two routs considered here are Jeddah to Medina (JED to MED) and Jeddah to Riyadh (JED to RUH). All trips would be assumed as round trip flights. Table 1 shows the selected engine type for the study

TABLE 1: Aircrafts Specification

Aircraft Type	**Engine Type**
B737-500	CFM56-3B1R
A 319	CFM56-5A4
A320	CFM56-5B4/P

II. METHODOLOGY

The first step in all scenarios was to determine the flight utilization. This was done by stating values for the time to climb and descend, and the associated climb and descent speed, along with various associated distances.

The take-off weight of each of the aircraft is calculated by the weight fraction method as identified in Figure 1, Ref [1]. Since the empty weight was known for each aircraft, the total weight and fuel weight is easily determined.

The first step would be to calculate the payload weight Wpl from eq 1

$$Wpl = number\ of\ passengers \times (174 + 40) \quad (1)$$

The second step would be to calculate the fuel weight Wf from eq 2

$$Wfl = (1 - Mff)Wto \times Wfuel\,res \quad (2)$$

Where M_{ff} if the fuel fraction calculated, the fuel fraction ware calculated in each phase of flight, startup, taxi, take off, climb, decent and landing

The W_{to} is the assumed takeoff weight for the aircraft at this flight, While the fuel fraction in cruise is calculated from eq 3

$$Rcr = \left(\frac{Vcr}{Cj}\right)\left(\frac{L}{D}\right) In\left(\frac{W4}{W5}\right) \quad (3)$$

Where

$\left(\frac{L}{D}\right)$ Lift to drag ratio

C_j specific fuel concumtion in lb/lb/hr

V_{cr} aircraft crusing speed in kts

R_{cr} cruise range in n.m

The thread step would be to calculate the operating weight empty Woe eq 4

$$Woe = Wto + Wf + Wpl \quad (4)$$

The forth step would be to calculated the empty weight from eq 5

$$Wetent = Woe + Wtfo + Wcrew \quad (5)$$

Where

W_{crew} from mission specification

W_{tfo} trapped fuel and oil

W_{tfo}=5% W_{to}

The empty weight then is compared from the empty weight allowable from Refl eq6

$$We = inv.Log\{\frac{LogWto - A}{B}\} \quad (6)$$

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Where A, and B are constant from page 47, Ref [1], table 2.15

If the error between W_{etent} calculated and W_e is less than 5% then the W_{etent} is acceptable and W_f, and W_{to}, are acceptable if not change the W_{to}

Note: all dimensions are in lb

Figure 1 summarize the process in which all weights are calculated

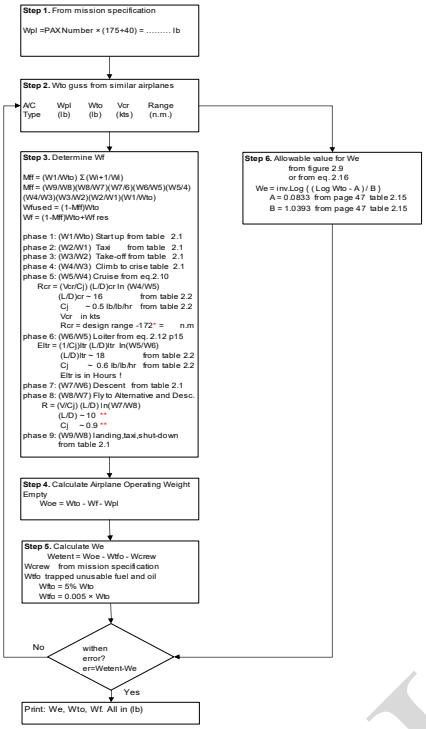


Fig 1: Calculating the fuel and takeoff weight through the weight fraction method Ref[1]

Next the actual Direct Operating Cost DOC, components is calculated. The DOC is calculated by using the method used in Ref [2], starting with the DOC of flight. Within the DOC of flight the cost of the crew, fuel and oil, and insurance all can be directly determined. All values for the crew cost were assumed based on the values from the local airline and Ref [2]. As were the input values for the fuel and oil cost and insurance.

TABLE 2: Some data given Ref[3]

Parameter		Value
Annual salary paid for one pilot	[$/year]	100000
Annual salary paid for for one co-pilot	[$/year]	80000
Cost of maintenance materials for airplane	[$/n.m]	404
Cost of maintenance materials for engine	[$/n.m]	217
Annual hull insurance rate	[$/$/year]	0.015
Maintenance manhours per flight hours	[hrs/hr]	5.86
Number of flight hours / year		750
Fuel density FD	[lbs/gallon]	8
Fuel price FP	[$/gallon]	1.4
L / D		15
engine maintenace labor rate	[$/hr]	12

$$DOC = DOCfly + DOCmaint + DOCdepr + DOClnr + DOCfin \quad (7)$$

Where:

DOCfly is the direct operating cost of flying in $/n.m.

DOCmaint is the direct operating cost of maintenance in $/n.m.

DOCdepr is the dirct operating cost of depreciation in $/n.m.

DOClnr is the direct operating cost of landing fees, navigation fees, and taxesin $/n.m.

DOCfin is the direct operating cost of finance in $/n.m.

n.m. nautical miles

The DOCfly is given by

$$DOCfly = Ccrew + Cpol + Cins \quad (8)$$

Where:

Ccrew is crew cost given by

$$Ccrew = SUM [(n_{cj}) { (1+ K_j) / V_{bl} } (SAL_j / AH_j) + (TEF_j / V_{bl})] \quad (9)$$

nc_j is the number of crew member of each type (i.e. captain, and co-pilot)

V_{bl} is the airplane block speed in n.m/hr.

SAL_j is the annual salary paid to crew members of each type

AH_j is the number of flight hours per year of each type

TEF_j is the travel expense factor

K_j factor which accounts for items such as vacation pay, cost of training

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Cpol is the fuel and oil cost per nautical mile given by

$$Cpol = 1.05 (Wf / R) (FP / FD) \quad (10)$$

Wf is the fuel weight in lb

R range in n.m

FP is the price of fuel in $ / gallon

FD is the fuel density in lbs / gallon

Cins is the airframe insurance cost in $/n.m given by

$$Cins = (fins) (AMP) / \{ (Uann) (V_{bl}) \} \quad (11)$$

fins is the annual hull insurance rate in $/$/year

AMP is the airplane market price

Uann is the annual hour utilization

The DOCmaint is given by

$$DOCmaint = Clab/ap + Clap/eng + Cmat/ap + Cmat/eng + Camb \quad (12)$$

Where

Clab/ap is the labour cost of airframe and systems in $/n.m

$$Clab/ap = 1.03 (MHRa) (R / V_{bl}) \quad (13)$$

MHRa is number of airframe and systems maintenance hours needed per block hours

Clap/eng is the labour cost of engines in $/n.m

$$Clap/eng = 1.03 (1.3) Ne (MHRe) (R / V_{bl}) \quad (14)$$

Ne number of engines

MHRe is the number of engines maintenance hours needed per block hours

Cmat/ap is the cost of maintenance materials for the airframe and systems $/n.m

Cmat/eng is the cost of maintenance materials for the engines $/n.m

Camb is the applied maintenance burden in $/n.m.

The DOCdepr is given by

$$DOCdepr = Cdap + Cdeng + Cdav + Cdapsp + Cdengsp \quad (15)$$

Where

Cdap is the cost of airplane depreciation without engines in $/n.m

Cdeng is the cost of engine depreciation in $/n.m

Cdav is the cost of depreciation of avionics systems in $/n.m

Cdapsp is the cost of the depreciation of airplane spare part in $/n.m

Cdengsp is the cost of the depreciation of engine spare part in $/n.m

The DOClnr is given by

$$DOClnr = Clf + C nf + Crf \quad (16)$$

Where

Clf the direct operating cost due to landing fees in ($/n.m) are calculated by

$$Clf = (Caplf) / \{ (V_{bl}) (t) \} \quad (17)$$

Where

Caplf is the landing fees per landing given by

$$Caplf = 0.002Wto \$/lbs \quad (18)$$

Wto is the airplane takeoff weight in lbs

Cnf the navigation fees in $/n.m

$$Cnf = (Capnf) / \{ (V_{bl}) (t) \} \quad (19)$$

Where

Capnf is the navigation fees charged per airplane per flight

Crt is the direct cost of registry taxies in ($/n.m) are calculated by

$$Crt = (frt) DOC \quad (20)$$

Where frt is a factor suggested from Ref[5]

$$Frt = 0.001 + (10^{-8}) Wto \quad (21)$$

Where

Wto takeoff weight in lbs

The DOCfin is given by

$$DOCfin= 0.07 DOC \quad (22)$$

In order to calculate the cost per aircraft per trip and the cost per seat mile, it is calculated as follows

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Cost per aircraft per trip = DOC [$/n.m] × Distance [n.m] (23)

Cost per seat mile = DOC [$/n.m] ÷ Number of seats (24)

More details are available in Ref [2].

The the DOC of maintenance was calculated, mostly based on the values from a local airline and values founded in Ref [2]. This was also true for the DOC of the depreciation, as well as the DOC of the landing and navigation fees. Once all of these components were calculated, the total direct operation cost could be calculated by just adding these values together, for each of the flight scenarios. The unite of DOC is dollars per nautical miles

After calculating DOC, and with the known distance and the seats for each aircraft at each sector, the cost efficiency chart could be generated and determined

TABLE 2: Direct Operating Cost in $ per n.m

Aircraft Type	DOC in $/n.m	
	JED - MED	**JED - RUH**
B 737-500	15.3	15.0
A 319	16.6	16.3
A 321	21.0	20.5

III. RESULTS

Figure 2,3 shows the efficiency of each aircraft at a given sector. Different aircraft types are not only compared with their trip cost but also with their seat mile cost, the lower the two parameters for the given aircraft the better, the aircraft is said to be more efficient if both parameters are low.

Figure 2, shows the cost efficiency chart results for the sector Jeddah to Riyadh, Figure 3, shows the cost efficiency chart results for the sector Jeddah to Medina.

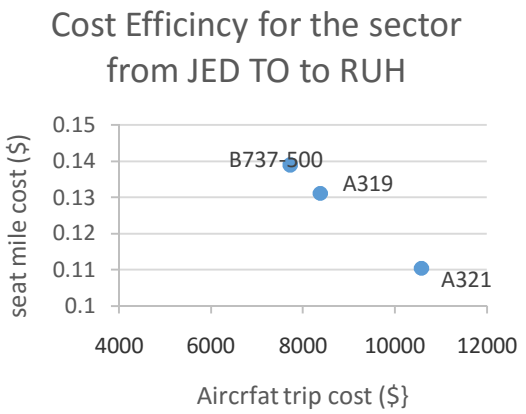


Fig2: Cost efficiency for the sector Jeddah to Riyadh

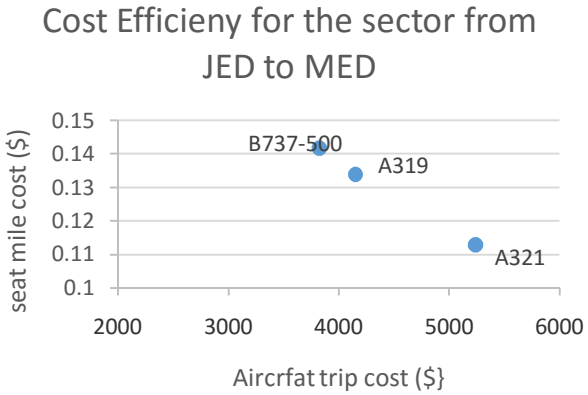


Fig 3: Cost efficiency chart for the sector Jeddah to Medina

IV. CONCLUSION

- In the cost efficiency chart the best-performed aircraft in this sector would be the lowest seat mile cost and the lowest aircraft trip cost.
- B737-500 has the highest seat mile cost but the lowest trip cost for each sector
- A321 has the lowest seat mile cost but has the highest trip cost
- Since it is preferential to have the lowest seat mile cost and the lowest trip cost the A319 performed better than the B737-500 and A321

REFERENCES

[1] Roskam, J., " Aircraft Design" Part I, Roskam Aviation and Engineering Corporation, Ottawa, Kansas, U.S.A, 1990.
[2] Roskam, J., " Aircraft Design" Part VII Airplane cost estimate , Roskam Aviation and Engineering Corporation, Ottawa, Kansas, U.S.A, 1990.

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