AE 725 AIR TRANSPORTATION

AUTUMN 2022-2023: July to November 2022

ASSIGNMENT NO 2 **WEIGHTAGE: 15%** **DEADLINE: 23:45 @ 29th Sep 2022**

This assignment is in two parts, Part-A (DOC related) and Part-B (Airline Scheduling related).

Part-A (Direct Operating Cost related) **10 Marks**

Each Team is assigned an Aircraft, as per the following table.

Team No	Aircraft
1	SAAB-340B
2	SAAB-2000
3	ATR 42-320
4	Dornier Do-328
5	DH Dash8-S-200
6	DH Dash8-S-300
7	Dornier Do-228
8	Jetstream-200
9	ATR 72-500
10	Bombardier Q-400

Refer APPENDIX (pg. 4-7 of this document) for the procedure and explanation of various components of DOC.

The Table below shows the results for a sample aircraft for a stage length of 400 nm.

Sample Aircraft	Purchased	Leased
T_{blk} (hours)	2.000	
U_{ann}	2880	
N_{ann}	1440	
C_{spare} (\$)	0.00	2280000
$C_{acequip}$ (\$)	14280000	
C_{depr} (\$)	595.00	95.00
C_{lease} (\$)	0.00	800.00
C_{intr} (\$)	495.83	79.194
C_{insur} (\$)	49.58	
C_{stand} (\$)	1140.42	1023.78
C_{crew} (\$)	480.00	
C_{fuel} (\$)	850.17	
C_{flight} (\$)	1330.17	
C_{mainta} (\$)	112.0	
C_{mainte} (\$)	203.5	
C_{maint} (\$)	315.4	
C_{land} (\$)	0.0	
C_{nav} (\$)	29.2	
C_{handl} (\$)	114.8	
$C_{airport}$ (\$)	143.9	
DOC per Trip (\$)	2929.9	2813.3
DOC/(pax)(nm) (\$)	0.1744	0.1675

The values of some input parameters needed for Sample Aircraft, and your aircraft are listed in Table below.

Name	Acquisition Cost	Max. Take Off Weight	No. of passengers	Airframe Weight	SHP @ Takeoff	Block Fuel	Block Time
Units	Million $	kg	--	kg	HP	kg	min
Symbol	C_{acq}	MTOW	N_{pax}	M_{airf}	SHPTO	F_{blk}	T_{blk}
SAMPLE A/C	12.00	17000	42	10500	2500	1400	120
SAAB-340B	9.00	12927	35	7711	1750	1170	120.2
SAAB-2000	15.50	22000	52	12955	3738	2316	90.0
ATR42-320	11.50	16700	46	9775	2386	1335	112.2
Dornier Do-328	8.50	13500	30	8369	1851	1374	105.0
DH Dash8-S-200	11.00	16466	37	9842	2150	1422	112.2
DH Dash8-S-300	12.00	19505	50	10124	2380	1521	118.2
Dornier Do-228	2.75	6400	19	3552	1040	977	141.0
Jetstream-200	2.50	5670	19	3805	1650	709	121.2
ATR 72-500	16.00	22800	68	13680	2475	1146	118.2
Q-400	21.00	28942	74	17365	5071	1605	99.6

Assume the following values as constant:

Stage Length = 400 nm   1 nm = 1.852 km   Fuel Cost = Rs 46 per kg   1$ = Rs. 75.75

1. Calculate the DOC components for the Sample Aircraft for Purchased and Leased cases and match your results with those mentioned in the Table given in the previous page.

2. Calculate the DOC components for the Aircraft assigned to you for Purchased and Leased cases and enter your numbers in the spreadsheet attached. Remember to insert the name of your aircraft in the first cell.

Part-B (Airline Scheduling related) **10 Marks**

The goal of this exercise is to compute a two-day flight schedule for a small regional airline in Maharashtra and Karnataka, which operates 3 identical turboprop aircraft (which we refer to as AC1, AC2, and AC3). The airline operates out of 4 airports: Mumbai (BOM), Kolhapur (KLH), Pune (PNQ), and Belgavi (IXG). The flight times are given in the Table. For example, the time from BOM to KLH is noted by looking at the row for BOM and the column for KLH, which we see is 60 minutes.

	BOM	KLH	PNQ	IXG
BOM	0	60	30	90
KLH	60	0	30	30
PNQ	30	30	0	60
IXG	90	30	60	0

You have to create a schedule for this airline, that includes 4 flights from each airport to every other airport (a total of 12 permutations x 4 flight legs each = 48 flights). These 48 flights are to be operated by the three aircraft in total (not 48 flights by each aircraft). You need to ensure that this schedule adheres to the following three constraints:

1. There should be no more than one aircraft at any airport (on the ground) at the same time.

2. Each aircraft should touch BOM airport at least once in the 2-day time window. Among these visits to BOM, each aircraft should spend at least 2 hours in a maintenance check. Note: The aircraft do not need to spend 2 hours at BOM in each visit. Each aircraft should spend 2 hours at BOM in just one of the visits. Constraint 1 as defined above still applies.

3. Each aircraft needs a minimum 30 minutes turnaround time after every flight. You can choose to hold any aircraft for additional time beyond 30 minutes at the airport, by marking the time period as 'Idle'.

4. PART-B of the enclosed spreadsheet template shows three initial flights, with AC1 flying PNQ-IXG, AC2 flying BOM-KLH, and AC3 flying IXG-BOM. Each student is assigned an initial schedule for the three aircraft, as listed in Table below.

Team No.	Initial Schedule
1	BOM-IXG, IXG-KLH, KLH-PNQ
2	BOM-PNQ, PNQ-KLH, KLH-IXG
3	PNQ-IXG, KLH-BOM, IXG-PNQ
4	PNQ-BOM, BOM-IXG, KLH-PNQ
5	IXG-PNQ, BOM-IXG, PNQ-KLH
6	IXG-KLH, KLH-BOM, BOM-PNQ
7	BOM-KLH, KLH-PNQ, PNQ-IXG
8	BOM-PNQ, PNQ-IXG, IXG-BOM
9	KLH-PNQ, PNQ-KLH, IXG-BOM
10	PNQ-BOM, BOM-PNQ, IXG-KLH

Ensure that your solution starts with these 3 flights at midnight on Day 1. The rest of the solution is totally up to you.

5. In Part-B of the spreadsheet template, fill in the entries in columns C, D, E, one for each aircraft. Each row marks a 30-minute time step, going up to 48 hours. Your solution must fit within this 48-hour time period (96 rows). A few sample entries are marked in the spreadsheet for your reference – delete them all before entering your answers. Note that the sample shows a violation of Constraint 1, as an example. You need to ensure that such an issue does not crop up in your solution. Your solution need not take up the full 48 hours if you don't need them.

APPENDIX
Procedure for Estimation of Direct Operating Cost (DOC)

The following stepwise procedure is suitable for estimation of DOC of twin-turboprop Commuter and Regional Transport Aircraft for operation on mostly domestic routes in India.

Note that there are separate formulae for estimation of some cost terms depending on whether the aircraft are owned by the airline i.e., Purchased, or Leased.

DOC is usually broken down into following components:

(a) Depreciation Cost C_{depr}
(b) Interest Cost C_{intr}
(c) Insurance Cost $C_{insur.}$
(d) Crew Cost C_{crew}
(e) Fuel Cost C_{fuel}
(f) Maintenance Cost C_{maint}
(g) Landing Charges C_{land}
(h) Navigation Charges C_{nav}
(i) Handling Charges C_{handl}

An important term on DOC is Standing Charges, or C_{stand}, which includes depreciation cost of the aircraft (C_{depr}), cost of repayment of interest on the borrowed capital (C_{intr}), and the cost of insuring the aircraft hull and the passenger (C_{insur}). In case of Leased aircraft, we need to add the Lease cost (L_{lease}) to the Standing Charges.

The sequential steps involved in the calculation of DOC are as follows: -

(a) **Calculation of block Time (T_{blk})**
Block time is the total elapsed time between chocks off and chocks on. It is given by the following relation, in which T_{stage} is the flight duration.

$$T_{blk} = (T_{stage}/ 3600) + 0.15 \qquad (1)$$

In most cases, T_{blk} is specified for a particular route.

(b) **Calculation of Annual Utilization time (U_{ann}) & Flights per annum (N_{ann}).**
Annual utilization (U_{ann}) of the aircraft (i.e., number of trips per year) depends upon number of flights flown and the frequency offered by the airline, which itself depends upon the demand for travel. Short-range aircraft usually have lower levels of utilization compared to long ones due to a much higher number of take-off and landings per flight hours. Hence, a maximum limit of 3600 operations per year is usually imposed for Commuter and Regional aircraft.

$$U_{ann} = T_{blk} .3600/(T_{blk}+0.5) \qquad (2)$$

The number of trips per year (N_{ann}) can be determined using

$$N_{ann} = U_{ann}/T_{blk} \qquad (3)$$

(c) **Calculation of Depreciation Cost C_{depr}.**
The cost of equipped aircraft to the operator includes the cost related to procuring and storing adequate number of spares related to Airframe and the Powerplant. In case the aircraft is purchased by the airline, Depreciation occurs on the procured Airframe and Powerplant, and on the Spares, but in case the aircraft are leased, then Depreciation occurs only on the Spares.

Assuming an 80%-20% split of Aircraft cost between Airframe & Powerplant, the cost of Airframe+Powerplant and/Spares can be calculated as follows.

For Purchased aircraft:

$$C_{acequip} = C_{acq} [0.8(1+F_{spaf}) + 0.2(1+F_{sppp})] \quad (4)$$

For Leased aircraft:

$$C_{spares} = C_{acq} [0.8(F_{spaf}) + 0.2(F_{sppp})] \quad (5)$$

Where

F_{spaf} = Aircraft spares cost factor = 0.15

F_{sppp} = Power plant spares cost factor = 0.35

C_{depr} can then be calculated based on assumptions regarding the useful life of aircraft and the residual value at the end of its life as:

For Purchased aircraft:

$$C_{depr} = C_{acequip} (1-F_{resval})/(N_{ann} F_{life}) \quad (6)$$

For Leased aircraft:

$$C_{depr} = C_{spares} (1-F_{resval})/(N_{ann} F_{life}) \quad (7)$$

F_{resval} = Aircraft residual value as fraction of original = 0.1

F_{life} = Useful operational life of aircraft = 15 years

(d) **Calculation of Interest Cost C_{intr}**

The average book value of the aircraft is used for calculation of C_{intr}

For Purchased aircraft:

$$C_{intr} = 0.5 C_{acequip} F_{inter}/N_{ann} \quad (8)$$

For Leased aircraft:

$$C_{intr} = 0.5(C_{Lease} + C_{spares}) F_{inter}/N_{ann} \quad (9)$$

Where F_{inter} = annual rate of interest on borrowed capital, assumed to be 10%

(e) **Calculation of Insurance Cost $C_{insur.}$**

$$C_{insur.} = C_{acequip} F_{insur}/N_{ann} \quad (10)$$

Where F_{insur} is the annual rate of interest for hull and passenger, usually assumed as 0.5%, i.e., F_{insur} = 0.005.

The Standing Charges C_{Stand} can thus be estimated as:

For Purchased aircraft:

$$C_{stand} = C_{depr} + C_{intr} + C_{insur} \quad (11)$$

For Leased aircraft:

$$C_{stand} = C_{depr} + C_{intr} + C_{insur} + C_{Lease} \quad (12)$$

Where, $C_{Lease} = (0.008 * C_{acq}) * 12/N_{ann}$

(f) **Calculation of Crew Cost C_{crew} and Fuel Cost C_{fuel}**

C_{crew} includes annual costs related to salary and allowances of the flight crew and the cabin attendants, and the cost associated with their training.

$$C_{crew} = T_{blk}F_{crew}\,(2 + 0.2*N_{fa}) \quad (13)$$

Where,

F_{crew} = Block hourly pay rate of the flight crew= $ 100
N_{fa} = No. of cabin attendants in the passenger cabin = 1/35 passenger.

The Fuel Cost, C_{fuel} is simply the product of Blok Fuel F_{blk} and the price of Fuel. Currently, the price of ATF can be assumed to be Rs. 46 per kg. In most cases, F_{blk} is specified for a particular route. The sum of C_{fuel} and C_{crew} is sometimes termed as Flight Cost, or C_{flight}

(g) **Calculation of Maintenance Cost C_{maint}**

C_{maint} has two main constituents, C_{mainta} and C_{mainte} related to the Airframe and the Powerplant.

The calculation of maintenance cost components can be quite cumbersome and complicated. If a detailed cost breakup for a specific class of aircraft is available, then the maintenance costs for another aircraft of the same class can be obtained by scaling up the cost components as a function of Airframe and Powerplant related parameters.

For a twin-turboprop aircraft, these cost components can be scaled up for the known maintenance cost breakdown of Dash-8-300 aircraft, using Airframe mass ($M_{\underline{airf}}$) as a scaling parameter for all Airframe related maintenance cost components, and Take Off SHP (SHPTO) for all Powerplant related maintenance cost components, using the following relations :-

$$C_{mainta}= \sqrt{}\,(M_{airf}/10124).\ [F_{ampt} + F_{alpt}*F_{mhr} + T_{blk}\,(F_{ampfh} + F_{mhr}*F_{alpfh})] \quad (14)$$

Where,

M_{airf} = Airframe mass in kg (can be assumed as 60% of MTOW, if exact value is not known)
10124= Airframe mass of Dash-8-300 in kg
F_{ampt} = cost of material per trip for Airframe maintenance ($14.32)
F_{alpt} = Man-hours per trip for Airframe maintenance (0.7)
F_{mhr} = Man-hour rate for Airframe maintenance ($18.8/hr)
F_{ampfh} = cost of material per flight hour for Airframe maintenance ($21.49)
F_{alpfh} = Man hours per flight hour for Airframe maintenance (1.05 hrs)

$$C_{mainte}=\sqrt{}\,(SHPTO/2380).\ [F_{empt} + F_{eopt} + F_{elpt}*F_{mhr} + T_{blk}\,(F_{empfh} + F_{eopfh} + F_{elpfh}*F_{mhr})] \quad (15)$$

Where,

SHPTO = Engine power at max Takeoff rating (HP)
2380 = Engine power at max Takeoff rating for Dash-8-300 (HP)
F_{empt} = cost of material per trip for Engine maintenance ($7.24)
F_{eopt} = cost of material per trip for Engine overhaul ($18.87)
F_{elpt} = Man-hours per trip for Engine maintenance (0.04)
F_{mhr} = Man-hour rate for Engine maintenance ($18.8/hr)
F_{empfh} = cost of material per flight hour for Engine maintenance ($10.86)
F_{eopfh} = cost of material per flight hour for Engine overhaul ($ 74.69)
F_{elpfh} = Man-hours per flight hour for Engine maintenance (0.015 hrs)

(h) **Calculation of C_{land}**

The charges levied towards landing fee depend on the policy in force at the airport, and vary from country to country, and sometimes even from airport to airport within a country. The current rate changed by AAI for domestic flights in India is as follows:-

MTOW (kg)	Landing Charges (Rs.)	
Upto 10,000 kg	Rs. 67.10 per 1,000 kg	
10,001 kg to 20,000 kg	Rs. 671/- Plus Rs. 117.70 per 1,000 kg in excess of 10,000 kg	(16)
Over 20,000 kg	Rs. 1848/- Plus Rs. 231/- per 1,000 kg in excess of 20,000 kg	

It may be noted that, currently, AAI, has waived Landing Charges for aircraft with a maximum certified capacity of less than 80 seats, being operated by domestic scheduled operators at all non-major airports, Helicopters of all types, and Approved Flying school/ flying training institute aircrafts.

(i) **Calculation of C_{nav}**

The charges are also called RNFC, i.e., Route Navigation and Facilitation Charges. The following formula is used to estimate RNFC charged by AAI for domestic flights operating in India, which consists of a fixed amount that is scaled up as a function of distance travelled and aircraft MTOW.

RNFC for Landing Flights = Rs. (R x D x W), where,
R = Rs. 4620/-
D = √ (GCD/100), with maximum value of GCD as 1200 nm
GCD = Great Circle Distance, which can be assumed as 1.05 * Stage Length
W = √ (MTOW/50000), with maximum AUW as 2,00,000 kg

It may be noted that, currently, AAI gives discounts in RNFC for small aircraft operating in domestic routes in India. There is 80% discount for aircraft with MTOW ≤10,000 kg, and 60% discount for 10001 kg ≤ MTOW ≤ 20000 kg. These is no discount for aircraft with MTOW ≥ 20001 kg.

(j) **Calculation of C_{handl}**

The Handling Charges, i.e., C_{handl} are also a function of local policies in force at the airport.

In India C_{handl} consists of two components, a passenger facilitation service fee, and passenger security service fee. The rates for these fees being charged currently by AAI are as follows:

	Domestic	International
Pax. Service Fee (Facilitation)	Rs 77 per pax	Rs 89 per pax
Pax. Service Fee (Security)	Rs 130 per pax	Rs 130 per pax
Total C_{handl}	Rs 207 per pax	Rs 219 per pax

The sum of C_{land}, C_{nav} and C_{handl} is termed as $C_{airport}$

Thus, DOC for one trip can be calculated using:

$$DOC_{trip} = C_{stand} + C_{Flight} + C_{Maint} + C_{airport} \tag{18}$$

A useful figure of merit for comparing the aircraft operating cost is the DOC per seat per nautical mile:

$$DOC_{snm} = \frac{DOC_{trip}}{N_{pax} \times X_{stage}} \tag{19}$$

DOC_{snm} is usually evaluated in cents per seat per nautical mile and is frequently quoted in Air Transport literature.