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Evaluation and Selection of a Fleet of Aircraft for a Local Airline

Wail I. Harasani

Aeronautical Engineering Department, Faculty of Engineering, King Abdulaziz University, Jeddah, Saudi Arabia

Abstract. The present work simulates the evaluation and selection of a fleet of aircraft for an airline located in Jeddah, Saudi Arabia, in an assumed network that includes both local and international destinations. This is carried out through a series of phases and subsequent levels of analysis. At the end of these phases some recommendations are given for selecting the suitable fleet. The phases are simulated using MS Excel and the output of the study predicts both the aircraft efficiency and its contribution to the net profit of the airline. With the given range and payload a number of candidate aircraft has been chosen for the study. Finally, it was found from the study that 11 of the EMB145 aircraft would be the best choice for the proposed airline.

1. Introduction

The nature of this paper is in the field of airline fleet planning, a selection of a fleet of aircraft for a proposed start-up airline in Jeddah, Saudi Arabia. Aircraft manufacturers usually represent their aircraft to their customers in the following four categories:

- Aircraft specifications
- System configuration equipment
- Cabin configuration
- In flight entertainment configuration

The Aircraft specifications would include the aircraft dimensions, performance, weights, and interior. Cabin configuration (*i.e.*, whether the aircraft has a single, two or three classes) and system configuration would depend on the client needs. System configuration, could include the type of engine used, and the in-flight entertainment system in the aircraft are considered as selectable items. The selection would depend on several factors such as the predicted passenger load factors, the desired airline image to the flying public and the competition environment.

Airlines, on the other hand, have their own structure. Understanding the airline operation and structure is an important step for better understanding of the airline world and its behaviour with different aircraft designs, and when to buy, sell, or rent an aircraft. Important information should be known about the airline to investigate the suitability of a given aircraft for a given airline. This information should include such items as the capacity and number of hangars, if they outsource some of their maintenance, or outsource some tasks or services, and the number of employees, and their salaries. A given aircraft would be suitable for a large carrier but not suitable for a small carrier.

For any maintenance, repair, inspection, or material handling on the aircraft, the Maintenance Planning Document (MPD) that is supplied by the manufacturer deals with these issues. The MPD gives guidelines for *Base Maintenance* and *Line Maintenance* for the aircraft in its operation duration and when it should be carried out. From the maintenance operation, maintenance labour rate for engines and aircraft is required. The base maintenance would include all major checks that need to be carried out in a hanger usually in the base, but the line maintenance are tasks done after every flight or day for the aircraft.

Ground time or turn round time is an important issue to the airline industry. It is where aircraft, airline, airport, and air traffic control clearly interact. Ground time is important for the airline industry because the lower the ground time the higher the utilization of the aircraft and this would lower the direct operating costs. Ground time is also important for the airports. Lower ground time reduces congestion at the airport. The airports would then handle more travellers.

To make a successful plan, a fleet planner must take this time into consideration quite early in the planning stage. Therefore, Ground time is taken into consideration while building the airline fleet plan model. In real life each aircraft has its ground time, which depends on a number of elements such as range of flight, is the flight domestic or international, is the aircraft at the base or not, the capacity of the flight, the design of the aircraft, and other factors.

2. Fleet Planning

Fleet planning is very important for any airline. Fleet planning determines what type of aircraft the airline should buy, and how many of them, in order to achieve the airline goals. Fleet planners also get involved in the negotiation deals with aircraft and engine manufacturers, most of the decision making would be through fleet planning. So by understanding basic elements of fleet planning one would essentially understand the airline needs and operation parameters.

It should be noted that there are other factors that influence the buying of a new aircraft that do not depend on fleet planning, such as alliance, people factors and communality [1].

For example Airbus in marketing their Aircraft by claiming that communality exists between their aircrafts and the advantage of having a fleet of different type sizes of aircraft from Airbus would:

- Because of the communality that exist, less time is needed in training pilots from flying one type of aircraft to another.
- Also less time in training maintenance manpower from maintaining one type of aircraft to another.
- Since the systems are similar and properly use the same tools and procedures for maintenance or even operation such as refuelling, or baggage handling, that would have a big effect on the operational costs.

The only main disadvantage of communality is that if having the whole fleet of the same type of aircraft, it is difficult to change and the airline would not be in a good position in the negotiation for a new aircraft with the manufacturers, while if they have a mix fleet they can buy one aircraft type or another so that would help them get a better price of the aircraft needed.

It is important to note that fleet planning is not just aircraft evaluation, aircraft comparison, route analysis, aircraft acquisition, or matching supply to demand in isolation, but includes all these elements simultaneously [1].

A better understanding of fleet planning decision making and the evaluation of an aircraft in an airline would help construct the flight model. One of the most difficult decisions in an airline is whether to buy a new or a used aircraft, and what type, or renew the existing aircraft.

The dilemmas of fleet planning of an airline is that

- The fleet is highly complex
- Decisions must be long term
- Market is volatile
- Networks are heterogeneous

So fleet planning is a compromise and is inevitable as there is no exact right solution.

Each airline has a different approach towards the replacement of its aircrafts. There are *large airlines which are government supported*, *small airlines*, or *capital rich airlines,* all would have a different aircraft average age, but they all follow the simpler principle of fleet planning.

Fleet planning is an on going process over the life cycle from the evaluation through disposal and data collection. More details are available in Ref. [1].

3. Approach

The emphasis will be on the interaction between all of the above-mentioned elements. Establishing the model would help in the decision making of the fleet planning.

Modelling remains an important step to gain an understanding of how the air transport world acts and interacts. It represents the most challenging task, due to the large number of fields that need to be covered and their mutual interaction in building up the flight model.

Typically fleet planning evaluation and selection in the airline for a number of aircraft is broken down into five main steps as shown in Fig. 1[2].

These steps are:

1.*The Process of Aircraft Selection*. The first set of input data for this step would be from the airline in the process of selecting an aircraft, the input data would be a*irfield data* which includes (elevation, temperature, runway length and surfaces, … etc). The selection is based on the operation of regional jets from Jeddah to selected destinations in a network that includes local destinations such as Riyadh, and Dammam, and international destinations such as Beirut, Dubai, Cairo and Istanbul. Table 1, shows the airfield data for the mentioned cities. Table 2 shows the aircrafts that have been selected for the study, their engine type and the associated weights. The second source of information would be the

Market Forecast, Table 3, includes assumed data such as growth rates, frequency, saturation load,… etc.

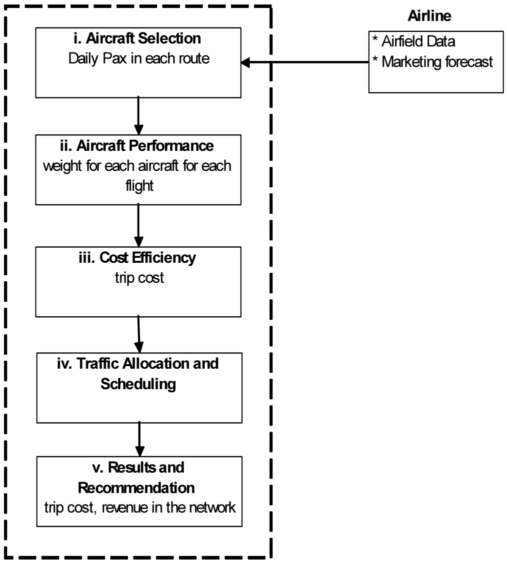

Fig. 1. Typical practical steps in fleet planning.

Table 1. Airfield data.

Airport (+IATA)	Elevation ft	Runway length ft	Avg. Temp C
Jeddah (JED)	48	12491	25
Riyadh (RUH)	2049	13829	22
Dammam (DMM)	72	13165	16
Dubai (DXB)	34	13143	26
Cairo (CAI)	382	13127	21
Beirut (BEY)	85	12545	19
Istanbul (IST)	163	9813	17

Table 2. Aircraft types [3].

Aircraft Manufacturee	Aircraft Type	Engine Type	OWM lb	MFW lb	MTOW lb
Embraer	EMB145(LR)	AE3007A1	26586	11435	48500
Bombardier	CRJ-700E	CF34-8C1	43500	19450	75000
Embraer	EMB170	CF34-8E	46165	20887	79344
Avro (BAe)	Avo RJ85	LF 507	53700	22750	97000
Boeing	B717-200	BR715-30	68500	29500	121000
Airbus	A318-200	CFM56-5	84600	42080	145500

Note: They all have an Auxilary Power Unit.
OWM: Operating Weight Empty
MFW: Max. Fuel Weight
MTOW: Max. Takeoff Weight

The last set of information needed in this process is domestic, regional, and international network distances. After making an analysis the output of this step would be the daily passenger profile for every sector in the long and short term and a payload range plot. The candidate aircrafts would then be determined in this step.

2. *Detailed Aircraft Performance*. In the previous step the candidate aircraft has been identified. Therefore, the performance of each aircraft can be known, the airfield and en-route capabilities of these aircrafts will be examined. After setting up some ground rules such as time for taxi-in, time for taxi-out, time for start-up, the reserve fuel, the assumed alternative airport…etc all for domestic and international routes, the output would be a weight breakdown and passenger payload in the network for each nominee aircraft and that by using Roskam books[4, 5]. That would give an indication of how many passengers a given aircraft can take.

Table 3. Market forecast.

Sector IATA Code From To	Ann. Pax Each way	Growth p.a. (%)	Frequency	Staturation Load %	Yield $/nm
JED - RUH	24000	5	2D	85	0.25
JED - CAI	36000	5	3D	85	0.25
JED - BEY	8000	10	D	85	0.25
JED - DXB	24000	10	D	85	0.25
JED - IST	42000	10	2D	75	0.25
JED - DMM	16000	10	3D	80	0.25
RUH - CAI	12000	10	2D	86	0.25
RUH - BEY	8000	10	2W	86	0.25
RUH - DXB	15000	5	2W	87	0.25
RUH - IDT	11000	10	2W	85	0.25

p.a.: per annum
D: daliy flights
W: weekly flights
Ann. Pax: Number of passengers yearly each way

3. *Cost Efficiency.* This step will indicate the economic suitability for each aircraft on a typical stage length or cost per trip. In this step some assumptions must be made to progress the economic analysis. Examples of these assumptions would be fuel cost, cost of maintenance, annual insurance rate, annual salaries paid, ... etc, as shown in Table 4. The specific fuel consumption was given as specified by the manufacturers. The dollar year was assumed to be 2006. The engine maintenance labour rate used is $12 per man hours, and the fuel price is assumed to be $ 1.4 per US Gallon. Direct Operating Cost (DOC) calculations were based on methods mentioned in Ref. [5] . DOC is an

area where it is very tricky to get a third party reliability data source and airlines are very reluctant to provide data on their cost per stage length.

Table 4: Assumed Parameters.

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

The output would be a cost per trip per aircraft on the given network.

$$DOC = DOCfly + DOCmaint + DOCdepr + DOClnr + DOCfin \qquad (1)$$

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 taxes in $/n.m.

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

n.m. nautical miles

The DOCfly is given by:

$$DOCfly = Ccrew + Cpol + Cins \qquad (2)$$

Where:

Ccrew is crew cost given by:

$$Ccrew = SUM\,[\,(n_{cj})\,\{(1+K_j)/V_{bl}\}\,(SAL_j/AH_j) + (TEF_j/V_{bl})\,] \qquad (3)$$

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

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

$$Cpol = 1.05\ (Wf / R)\ (FP / FD) \quad (4)$$

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

$$Cins = (fins)\ (AMP) / \{ (Uann)\ (V_{bl}) \} \quad (5)$$

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:

$$DOCmaint = Clab/ap + Clap/eng + Cmat/ap + Cmat/eng + Camb \quad (6)$$

Where:

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

$$Clab/ap = 1.03\ (MHRa)\ (R / V_{bl}) \quad (7)$$

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

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

$Clap/eng = 1.03\ (1.3)\ Ne\ (MHRe)\ (R / V_{bl})$ (8)

Ne is 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 (9)

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 (10)

Where:

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

$Clf = (Caplf) / \{ (V_{bl}) (t) \}$ (11)

Where:

Caplf is the landing fees per landing given by:

Caplf = 0.002Wto \$/lbs (12)

Wto is the airplane takeoff weight in lbs

Cnf the navigation fees in \$/n.m

$$Cnf = (Capnf) / \{ (V_{bl}) (t) \} \quad (13)$$

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

$$Crt = (frt)\, DOC \quad (14)$$

Where frt is a factor suggested from Ref. [5].

$$Frt = 0.001 + (10^{-8})\, Wto \quad (15)$$

Where:

Wto takeoff weight in lbs.

The DOCfin is given by:

$$DOCfin= 0.07\, DOC \quad (16)$$

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

$$\text{Cost per aircraft per trip} = DOC\ [\$/n.m] \times \text{Distance}\ [n.m] \quad (17)$$

$$\text{Cost per seat mile} = DOC\ [\$/n.m] \div \text{Number of seats} \quad (18)$$

More details are available in Ref. [4, 5].

4. Traffic Allocation and Scheduling. This step will identify the quantity of each aircraft required and schedule the flights. This would require some information such as ground time for each aircraft, refuelling time and other information or rules supplied by the commercial management department, such as, daily frequencies for a given aircraft on each route, international flight linked to domestic flights, and other ground rules such as aircraft limited to operating between 06:00 and 23:00 or frequency for international routes should be either 3 times a week or once a day. The output of this step is a flight schedule.

5. Results and Recommendation. Which should identify the preferred fleet choice by comparing trip costs, revenue, operating costs, results, or total number of passengers, … etc with time.

4. Assumptions

In order to get the cost information about the airline, some relevant economic and operational data were either assumed or collected with the help of Saudi Arabian Airline.

In creating the model, some ground rules are assumed:

1.All maintenance checks are performed in the base airport.

2.There is at all times, at least one aircraft should be at stand by for emergency circumstances

3.The aircraft should undertake an inspection after each flight.

4.General ground rules have been assumed for time for different statuses such as passengers embark, refuelling, passengers disembark, repair, inspection …etc.

5. Results

An Excel programme created by the author was used to generate data for each aircraft type, by running the programme for 1, and 5 years, generating DOC, net contribution to profit for each sector, and total contribution to profit for the entire fleet after 5 years. This provides a visualization of the impact of each aircraft type. The output information can be used by a Project Manager, or a Fleet Planner, to decide on which aircraft would provide the best benefit or best results during operation in time for the money spent in case of the fleet planner.

The study also shows that for the given annual passenger traffic and the growth rate the airline would need 11 aircraft from the EMB145, or 8 aircraft from the CRJ-700, or 8 aircraft from the EMB170, or 6 aircraft from the AvoR85, or 5 aircraft from the B717, or 5 from the A318 aircraft.

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

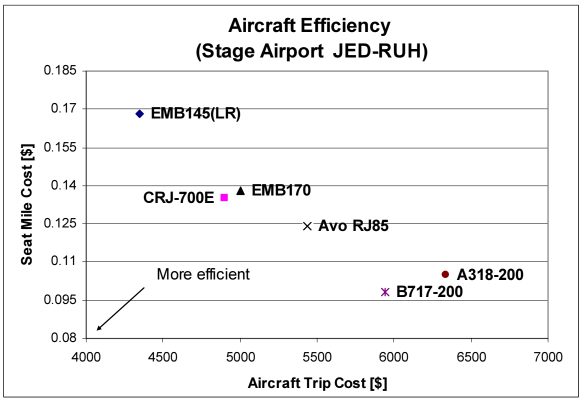

Fig. 2. Aircraft efficiency.

Figure 3 summarizes the study made for the 5 year time line for each aircraft operation on the assumed network. It shows that the first year would demonstrate a loss for all aircraft types. That would be predictable since the cost is high at the first year, when a new aircraft is introduced to an airline, but then costs would come down and stabilize at a given rate, then after 15 to 20 years cost would go up due to aging.

After 5 years cost is in its low curve and the growth factor is taken into account, so the contribution to profit would show revenue.

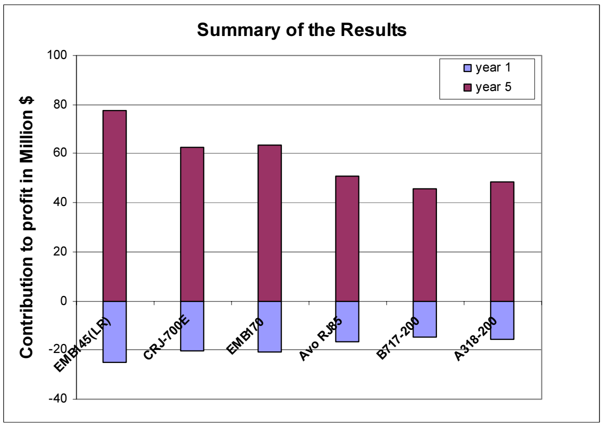

Fig. 3. Study results.

5. Conclusion

The results predict the aircrafts efficiencies, and the total contribution to profit. The following can be concluded from Fig. 2:

- While EMB145 aircraft has the highest seat mile cost, it has the lowest trip cost.

- The B717 has the lowest seat mile cost, but a high trip cost.
- The A318 has the highest trip cost but a low seat mile cost.
- An optimal efficiency aircraft would be that has a low seat mile cost and a low trip cost per sector.

From the results of the study in Figure 3 it would be concluded that:

1.The best choice for the given network that has the highest contribution to profit would be 11 of the EMB145 aircraft.

2.The worst choice for the given network would be the B717, since it has the lowest contribution to profit.

3.The EMB170 would be an excellent choice for potential market expansion, since the EMB170 is the 2nd best choice.

4.In terms of operational flexibility, the EMB170 would be able to fly additional markets.

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تقييم واختيار أسطول طائرات لخطوط جوية محلية

وائل إسماعيل هرساني

قسم هندسة الطيران – كلية الهندسة – جامعة الملك عبدالعزيز – جدة، المملكة العربية السعودية

المستخلص. يحاكي هذا البحث عملية المفاضلة والاختيار لأسطول من الطائرات لخطوط طيران مفترضة مركزها جدة في المملكة العربية السعودية مع افتراض شبكة من المطارات الداخلية والخارجية تسير رحلاتها إليها. ويتم ذلك من خلال سلسلة متتالية من الخطوات. وبعد انتهاء هذه الخطوات يتم إعطاء بعض التوصيات لاختيار الأسطول المناسب من الطائرات. وقد تم استخدام برنامج إكسل في أعمال الدراسة. والمخرجات من الدراسة تقيم كفاءة الطائرات ومساهمتها في الأرباح الصافية للخطوط المفترضة، من خلال المدى والحمل الأجر المعطاة تم اختيار عدد من الطائرات ، وفي نهاية هذه الدراسة اتضح أن ١١ طائرة من نوع EMB 145 هي الأنسب لهذه الخطوط المفترضة .