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# Using an operating cost model to analyse the selection of aircraft type on short-haul routes

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The airline industry is characterised by various challenging factors, including high capital costs, high operating costs and low profit margins. In the African situation, modernisation of fleets has been forced on the airlines by stricter noise and security regulations. Even though governments have resorted to privatisation, few investors are interested in airlines. They charge high airfares, but are nevertheless continually operating at a loss. The aim of this article is to use a recently developed operating cost model to analyse suitable choices, in terms of cost-related parameters, of aircraft commonly used on short-haul routes within Africa. All the parameters that are crucial in analysing a transport service are addressed, and the effect of passenger volume is analysed. The model was applied to a specific route within Africa, and subsequently to varying passenger numbers, in order to select the least costly aircraft. The results showed that smaller capacity aircraft, even though limited by maximum range, are the most economical to run, even when the frequency of flights is high.

## INTRODUCTION

Kane (1996) states that the airline industry provides a transport service for passengers and freight for an agreed price over long distances. It has the advantage that it is a safe and time-saving means of travel and in most cases is the only effective link between continents.

This industry is characterised by the following:

- It is a service industry in which no actual goods are exchanged.

It is a highly capital-intensive industry that needs large sums of money to operate.

It is labour intensive, with labour contributing a high percentage of operating costs.

On average, it operates within thin profit margins of about 1-2% on turnover annually.

- It experiences seasonality in passenger demand, such that airline revenue fluctuates throughout the year.

In addition to these crucial characteristics, the airline industry has been going through some significant changes. These have been brought about mainly because, historically, airlines were run by governments but, owing to a lack of proper management and high operation and maintenance costs, most have been privatised or have closed down operations.

The chairman of the African Airline Association (AFRAA 2000) commented:

[T]he modernization of fleets has been forced on the airlines by the stricter

noise and safety regulations and the need to improve Africa's air transport services and industry. With all of the above problems, privatization of airlines and foreign alliances has been adopted for several African airlines but with only a few successes. There are few investors interested in airlines that continually operate at a loss.

Doganis (1989) states that the costing of an airline service is an essential input to many decisions taken by airline managers, including whether to run a service profitably along a given route. Airline route economics require optimum utilisation of aircraft to pay back the high cost of capital, but a balance must be achieved because the airline service has high running costs (fuel and labour).

The aim of this paper is to use an operating cost model to analyse suitable choices, in terms of cost-related parameters, of aircraft commonly used for short-haul routes within Africa. It investigates how service design aspects in the model, such as block time, flight frequencies, aircraft type, varying passenger numbers and fleet size, can be used to minimise route-operating costs.

The limitations of this article include certain aviation data being unavailable, so assumptions to overcome these were adopted in the model. The airline industry will be studied as a traditional passenger airline and not a specialised modern airline such as a low-cost carrier or freight carrier. Certain issues will not be considered, such as degree of freedom, airport capacity, route

Table 1 Equations for calculations of standing costs (Stratford 1973)

Components	Equations
Hourly Depreciation	$C_{total} (1-rv)/L *U$
Hourly insurance	$X * C_{total}/U$
Hourly interest	$i * C_{total}/U [1 - ((1-rv)(L-1))/2L]$
Where	$C_{total}$ = total cost of aircraft +engine rv= residual value (%) U= annual utilisation (hrs)
	i =annual interest rate (%) L = life (years) X =annual insurance rate

Table 2 Data sources

Collected data	Sources
Aircraft specifications	Jane's world aircraft, Jackson (1997)
Engine specifications	Jenkinson et al (2001)
Capital cost of aircraft (US\$ million)	Pyramid Media Group website (2000)
Fuel consumption (US gal/h)	Rolls Royce (2003)
Oil consumption (US gal/h)	Rolls Royce (2003)
Passenger service charge (US\$/passenger)	NDOT, South Africa (1998)
Landing fees (US\$/single landing)	NDOT, South Africa (1998)
Parking fees (US\$/24 hour period)	NDOT, South Africa (1998)

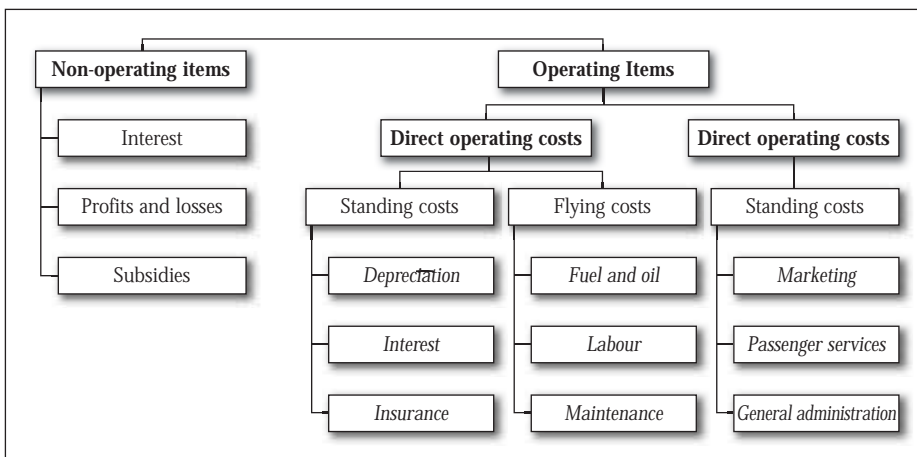


Figure 1 Operating cost breakdown

competition, bilateral agreements, time slots, environmental issues (noise and pollution), and the politics surrounding the airline business.

**OPERATING COST MODEL**

Ssamula (2004) developed a model that calculates the operating costs incurred by 11 aircraft commonly used by airlines on a specified route in Africa. A brief description of the operating costs is given in figure 1. The elements, equations and basis of determination are given in Ssamula (2004).

**The input component**

All the data that serve as input to the model, for example sector distance and annual passenger demand, at 60% load factor for a route, are included in the database. The user of the model can input the basic descriptors of the route for which the operating costs are to be calculated. He or she needs to specify the origin and destination countries for the airline service that is being costed. An automatic link then gives the default

values of sector distance and the weekly passenger demand for the corresponding airports from the database's matrix defining that route. The user also has the option of manually inserting dummy values in the section provided. From these route descriptors, the model calculates the minimum service frequency, which is the minimum number of flights required to meet the weekly passenger demand on that route, which also allows for dummy variables to be specified. The aircraft default values and aircraft technical specifications that also serve as an input to the model are included in the aircraft database.

**The calculation component**

The purpose of this sheet is to calculate the cost components for each of the 11 types of aircraft for the particular route.

Most of the cost component calculations are based on the number of hours with the unit of hours utilised. 'Utilisation' is defined as the average period of time for which an aircraft is in use on a particular route. It is calculated from the block time from 'engine-

on' to 'engine-off' of the aircraft, the round-trip time and the maximum flight frequency a single aircraft can fly on this route weekly. The fleet size is calculated depending on whether the maximum flight frequency of one aircraft can meet the minimum flight frequency needed to supply existing demand. Once the utilisation, fleet size and block time for the route have been calculated, each of the cost components is then derived, using the default values, equations and aircraft specifications for each type of aircraft.

**The output component**

This gives the total costs of running an aircraft on the route for a flight and for weekly flight frequency. The total costs for the total fleet on the route for the aircraft types both weekly and annually. The cost-related parameters for running the service are then calculated. Graphic outputs of the cost-related parameters are also given. All the aspects of route service design that are key to lowering the variable operating costs, including frequency of flights, sector length, block time and suitable aircraft selection, are addressed by the model.

**AIRCRAFT UTILISATION**

Doganis (1989) defines 'utilisation' as the average period of time for which an aircraft is in use. This is measured daily, monthly or yearly and the units for utilisation are given in block hours. Block hours are defined as the time for each flight or sector and are measured from when the aircraft leaves the airport gate/stand (engine on) to when it arrives on the gate/stand at the destination airport (engine off).

The economic life in years for which an aircraft is designed is given in terms of the maximum utilisation in hours. The utilisation of an aircraft is an important factor that needs to be calculated, since the major standing costs incurred on the aircraft should be paid over its economic life. According to Stratford (1973), these standing costs include all capital expenses that are incurred as a result of acquiring the aircraft as well as depreciation, insurance and interest. The equations for these standing costs are a function of the hours utilised within the economic life of the aircraft.

Table 1 gives a summary of these equations.

These equations show that the more the aircraft is utilised throughout its design life, the more it pays back the capital costs. Seemingly in aeronautics, the design life of an aircraft is given in terms of the number of hours it can be utilised. The equations above were stated by Stratford in 1973, but they have been updated to reflect current market conditions in terms of parameters such as residual value and annual insurance rate values. The equations used to calculate

operating costs are derived mostly from Stratford (1973), and the technical specifications used to calculate the costs are derived from sources given in table 2.

Utilisation has to be calculated from the block time and the number of flights a day within usable operating hours as shown below:

The number of usable hours in an operating day (H) is calculated as:

$$H = n t_f + (n-1) t_g \quad (1)$$

$$\text{Where } t_f = (R/V_b) + t_l \quad (2)$$

Where

H = the usable hours in the operating day

n = the number of flights per day

$t_f$  = the mean flight time per route (h)

$t_g$  = the average servicing time (h)

R = the mean distance per route (km)

$V_b$  = the average block speed of the aircraft (km/h)

$t_l$  = the average lost time (h)

Stratford (1973) suggests that for any given aircraft to be utilised efficiently, in a bid to spread out operating costs over its economic life, it will be in use for a maximum of 14 hours in any operating day, whether daytime or nighttime. Even though technology has changed over the years, the number of hours for which newer aircraft in the industry can operate on a flight is still at an average of 14 hrs for the long-haul 400-seater planes. This means the frequency of flights an aircraft can perform will be dictated by the usable hours in a day. The number of flights per day for a single aircraft is then calculated as:

$$n = H + t_g / ((R/V_b) + t_g + t_l) \quad (3)$$

And annual utilisation (hrs/year)

$$U = D.n.t_f \quad (4)$$

Where

D is defined as the serviceable operating days in the year

### Servicing time ( $t_g$ )

When the aircraft engine is switched off and the passengers depart, the aircraft has to undergo a number of activities that can be carried out simultaneously. These include servicing the engines, called 'check A', which involves detecting abnormalities with the system, leakages, etc, refuelling if necessary – especially for long journeys – cleaning, restocking beverages, and passenger loading. This process entails the standard procedures that should be carried out in servicing after an aircraft has landed and before it can fly out again.

At kulula.com (2003), a South African 'no frills' airline schedule for a popular route, the average servicing and refuelling time was calculated for all the aircraft to give a default

value of 54 minutes. Even though this airline is specialised, this value for servicing time was used in the model because the procedures are standard and are irrespective of the type of airline. This time was also assumed for larger aircraft, for which more manpower would normally be used.

### Lost time

Lost time takes into consideration the total time that is used when the aircraft is taking off and landing. This time includes the following procedures:

#### Ground manoeuvre time

This is defined as the sum of two periods: from the engine being started up to take-off time at departure; and from landing to the engine being switched off on arrival. This time depends on the length of the apron, taxiway and runway and the air traffic at the origin and destination airports.

Doganis (1989) and the Air Transport Association (ATA) (1963) both state that unless there is a weather problem, the ground manoeuvre time does not exceed 30 minutes, even for busy international airports, and ranges from 20 to 30 minutes.

#### Air manoeuvre time

The air manoeuvre time is defined as the time that the aircraft takes to climb to its cruise altitude at take-off and the time it takes to get to the ground from the flying altitude at landing. This take-off component is included within the block time and is when the aircraft burns most fuel and travels at relatively lower speeds. On short sectors, most of the flight time is covered by climb or descent time, but as the sector distance increases more time is spent at the cruising speed. Kane (1996) shows that the ATA quotes the average air manoeuvre time, regardless of sector length, as about six minutes.

### FREQUENCY OF AIRLINE SERVICE

The frequency of an airline service is defined simply as the number of times an airline will fly a route in a given time period, usually specified in a day or in a week. The frequency an airline provides along a route is designed to serve existing passenger demand at a level of utilisation of the aircraft that makes the route profitable. The frequency period could be specified as daily, especially for short-haul flights, weekly or monthly. In this article two aspects of frequency are identified:

- Minimum service frequency along a route is defined as the minimum number of flights that are needed to meet existing passenger demand.
- Maximum service frequency is defined as the maximum number of flights that a single aircraft can provide on a given route, irrespective of the passenger

demand. If the maximum service frequency of a single aircraft is less than the minimum service frequency along the route, the fleet size needs to be increased. High frequencies provide airlines with greater flexibility in schedule planning, thereby enabling them to increase aircraft and crew utilisation. Doganis (2001) states that airlines operating at low frequencies face the problem of what to do with their aircraft when they have completed the first round. On long-haul routes high frequencies also enable airlines to reduce the length and cost of crew stopovers.

Doganis (2001) states that economies from route traffic density arise because greater density enables the airline to use larger aircraft. These are more efficient, with lower costs per seat-kilometre and/or when operating at higher service frequencies, consequently at higher seat load factors, which lead to lower cost per passenger-kilometre.

### MODEL DEVELOPMENT

An operating cost model was developed by Ssamula (2004), using common operating cost components to calculate the cost of running an airline service along a route for 11 types of aircraft typically used by African airlines. These costs include capital costs, flying costs and exogenous costs incurred by an airline when flying a given route.

The lack of relevant data for African situations meant that many assumptions were made in the model. So that this model could be used to calculate operating costs on a short-haul route, service characteristic equations of the specified route, including block time, maximum and minimum weekly frequencies and fleet size, were developed from existing data sources and first principles as shown below.

#### Minimum service frequency

Minimum service frequency refers to the minimum number of aircraft trips required to meet demand. It is calculated by dividing passenger demand by aircraft passenger capacity:

$$\text{Weekly aircraft trips} = \frac{\text{Weekly passenger demand}}{\text{Aircraft passenger capacity}} \quad (4)$$

#### Block time

Block time is described as the time period in hours from 'engine-on' to 'engine-off', taking into consideration the lost time as the aircraft is taking off and landing (above). Acceleration and deceleration time losses are included in the time specified for take-off and landing. This is calculated as the time taken for a given aircraft mode to fly over a route whose sector distance is specified:

$$\text{Block time} = (\text{Distance/speed}) + \text{air manoeuvre time} + \text{ground manoeuvre time} \quad (6)$$

### Round trip time

This time is different from block time in that it represents the entire time taken for a round trip. It includes servicing and refueling (if necessary) before the aircraft can take off again at both ends.

The duration of this service time is taken as standard. That is, for larger aircraft, sufficient manpower could be employed to achieve the same time as for smaller aircraft.

The flight time is calculated in the model using:

$$\text{Round trip time} = 2 (\text{block time} + \text{servicing time}) \quad (7)$$

### Maximum daily service frequency

The supply that can be offered along this route is defined as the maximum number of flights a single aircraft can fly in a day. This is determined by the block time for a route length and regulations that specify how long any aircraft may fly per day, which is included in the usable operating hours for each aircraft. Value must be rounded off downwards, that is, 4.7 flights = 4 flights. The daily flight frequency is calculated as:

$$\text{Number of flights} = \text{Integer value of } \frac{\text{Usable operating hours}}{\text{Block time} + \text{Servicing time}} \quad (8)$$

### Maximum weekly service frequency

This is defined in this model as the number of flights that each aircraft can fly each week. This frequency is calculated by multiplying the maximum daily service frequency by the number of days in a week on which flying occurs. For a fixed schedule, where block time allows for only a single one-way flight a day, the maximum weekly number of flights is six one-way flights. That is, three return flights per week and 150 return flights a year are possible with one aircraft.

### Fleet size

The fleet size that will be needed to meet passenger demand depends on the maximum weekly frequency per aircraft and the standby fleet. The aircraft are assumed to be travelling the route at full capacity. A standby fleet (assumed to be 2%) is necessary to ensure that an aircraft is available when any of the fleet is undergoing maintenance. A standby fleet of 2% is meaningless for a fleet of fewer than 50 aircraft, but it implies that external aircraft could be leased or hired to provide the required service and this will incur an extra expense.

$$\text{Fleet size} = (1 + \% \text{standby fleet} / 100) * \frac{\text{Minimum weekly frequency}}{\text{Maximum weekly frequency}} \quad (9)$$

### Utilisation

For the model, the utilisation period is considered weekly and annually to calculate

the operating costs. Weekly utilisation is calculated as the product of weekly flight frequency and block time, while annual utilisation is a product of weekly utilisation and number of working weeks in a year, assumed to be an average of 50 weeks.

$$\text{Weekly utilisation (h/ week)} = \text{No of flights / week} * \text{block hours / flight} \quad (10)$$

$$\text{Annual utilisation (h/ year)} = \text{Weekly utilisation} * \text{weeks / year} \quad (11)$$

### MODEL OUTPUT

The model's output component calculates a range of cost indicators that are used to analyse the type of service being provided:

#### Cost per passenger-kilometre

This cost is a performance indicator, giving a measure of utilisation of the transport service. 'Passenger-kilometre' is the utilised output of a transport service and is calculated as the product of the number of passengers carried and the route length during the specified time. The cost per passenger-kilometre is calculated as follows:

$$\text{Cost / passenger-kilometre} = \frac{\text{Cost per given time period}}{\text{Passenger-kilometre (for same time period)}} \quad (12)$$

#### Cost per available seat-kilometre

This is a measure of the cost of providing the total quantity of service. The available seat-km represents the total quantity of service offered on the route and is defined as the product of annual aircraft-km and the aircraft capacity. Available seats in equation 13 represent the passenger capacity for any given aircraft. This is calculated as follows:

$$\text{Cost / available seat-kilometre} = \frac{\text{Costs per given time period}}{\text{Available seat-kilometre (for same time period)}} \quad (13)$$

#### Cost per aircraft-kilometre

The indicator gives a measure of how suited a specific aircraft is to the given route. Aircraft-kilometre is defined as the total distance flown by all the aircraft in the fleet in a given time period. This cost calculation is shown in equation 14:

$$\text{Cost/aircraft-kilometre} = \frac{\text{Costs per given time period}}{\text{Aircraft-kilometre (for the same time period)}} \quad (14)$$

#### Cost per passenger

This is calculated as the total operating costs for the service as a fraction of the passengers using the service. It is calculated in equation 15 by dividing the total operating costs for a given service over a given time period by

the number of passengers travelling during this period. It should be noted that passenger demand is seasonal; different costs could be determined for different periods of operation.

$$\text{Cost per passenger travelling} = \frac{\text{Costs per given the time period}}{\text{Number of passengers in the same time period}} \quad (15)$$

### Aircraft fleet utilisation

This gives an indication of how effectively the fleet size is being used along a route. It is defined as the average percentage of hours when aircraft are in use during an operational day, where the operational day consists of the maximum number of hours an aircraft can be in use (and not 24 hours), which for this article is a default value of 14 operational hours. This gives the ratio of the sum of the operating hours of all aircraft to fleet size as shown in equation 16. The higher this ratio is, the more effective the aircraft type and fleet size are. The units of this indicator in the model are aircraft-hours/aircraft/week. (This utilisation coefficient can also be computed annually.)

$$\text{Annual aircraft utilisation} = \frac{\text{Utilisation (for a given time period)}}{\text{Fleet size}} \quad (16)$$

### Work utilisation coefficient

This is defined as the ratio of the utilised service (pax-km) to the offered service (available seat-km), which is also termed 'the load factor'. Kane (1996) defines load factor as the percentage that revenue passenger-km constitute of the seat-km provided. This can be calculated by using the ratio of costs per passenger flying the route to costs per available seat-km to measure the economies of scale, determining how lucrative a route is in terms of providing the service and the service being utilised. A break-even load factor is computed for an aircraft type over any given route. It is equal to the percentage of the aircraft that must be filled by passengers or other traffic so that the airline can cover its direct operating costs for the flight. This point must obviously be reached when it can break even. That is, the cost of providing the service is equal to the fare from passengers utilising the service.

This ratio can be computed for a route for a specific aircraft type, during a specified period of time (hours, days, etc) or for an entire airline fleet on an annual basis. The higher this coefficient is, the better the fleet and service utilisation and the more economical its operation, even though higher utilisation coefficients indicate lower passenger comfort.

### MODEL APPLICATION

The model was then used to design a service for a specific route. This involves choosing

Table 3 Service changes with varying aircraft types

Route characteristics	Embraer Erj 135 JET*	Fokker F 50	Boeing 737-200	Boeing 737-400	Airbus A320-200	Airbus A340-200	Boeing 737-800	Boeing 767-200	Boeing 747-200	Boeing 767-300ER	Boeing 747-400
Weekly passenger demand (pax/wk)	577	577	577	577	577	577	577	577	577	577	577
Aircraft capacity (pax)	37	56	130	168	180	295	189	255	291	290	401
Minimum service frequency (Demand) (flights/week)	16	11	5	4	4	2	4	3	2	2	2
Weekly operating costs (US\$/year)	203 629	-	371 782	354 498	373 987	843 112	412 460	623 687	1 059 652	1 351 849	1 287 126
Cost per aircraft kilometre (US\$/aircraft-km)	4.24	-	24.79	29.54	31.17	140.52	34.37	69.30	176.61	225.31	214.52
Cost per passenger (US\$/pax) (at 100% load factor)	344	-	572	528	519	1 429	546	815	1 821	2 331	1 604
Cost per passenger flying (US\$/pax)	353	-	644	614	648	1461	715	1 081	1 837	2 343	2 231
Cost per available seat-km (US\$/seat-km)	0.11	-	0.19	0.18	0.17	0.48	0.18	0.27	0.61	0.78	0.53
Cost per passenger-km (US\$/pax-km)	0.12	-	0.21	0.20	0.22	0.49	0.24	0.36	0.61	0.78	0.74
Cost per hour utilised (US\$/hr)	3 103	-	16 719	21 197	22 796	105 804	24 516	51 595	137 547	175 817	170 152
Weekly aircraft Efficiency (aircraft-km/aircraft)	48 000	-	15 000	12 000	12 000	6 000	12 000	9 000	6 000	6 000	6 000
Weekly service use intensity (pax/aircraft-km)	0.01	-	0.04	0.05	0.05	0.10	0.05	0.06	0.10	0.10	0.10
Weekly fleet utilisation (aircraft-hrs/aircraft)	65.62	-	22.24	16.72	16.41	7.97	16.82	12.09	7.70	7.69	7.56
Work utilisation coefficient (pax/seat)	0.97	-	0.89	0.86	0.80	0.98	0.76	0.75	0.99	0.99	0.72

Table 4 Summary of cheapest aircraft type

Cost parameter	Aircraft type
Cheapest route costs	Embraer Jet 135
Maximum weekly frequency two flights	Airbus A340-200, Boeing 737-400
Maximum weekly frequency four flights	Airbus A340-200, Boeing 737-400
Load factor	Boeing 747-200 and 767-300ER
Highest weekly fleet utilisation and efficiency	Embraer 135 Jet
Highest weekly service use intensity	Boeing 747-200, 747-400, 767-300ER, Airbus A340-200

the least costly aircraft to run the route, with maximum efficiency and utilisation of fleet. The route characteristics that were used included a weekly passenger demand of 577 pax/week (ie 30 000 pax/year), irrespective of the direction and route length of 3 000 km.

Because of the level of accuracy of the model, aircraft within 10% of the least costly aircraft will be identified as suitable. The conclusions inferred from the analysis below are applicable only to this specific route and the costs are calculated from the number of flights for each specific type of aircraft. The aircraft that were not included were eliminated by the model because of technical limitations such as the maximum range. That is, the Fokker F50 is not suited to this route because its maximum range is 1 300 km.

### Frequency

■ Since the operating costs are calculated from the unit per hour utilised, the more

an aircraft flies, the higher the total operating costs. But the 37-seater Embraer jet, which flies eight times more than the Boeing 747-400, has total operating costs that are much lower than the total operating costs for the larger aircraft (which is the basic principle used by low-cost air carriers flying low seat-capacity planes at high frequencies, since the running costs are cheaper than those of larger aircraft).

■ Should an airport authority dictate the maximum flight frequency along a given route, a choice of least costly aircraft can still be made. For example, in table 3, using the minimum service frequency and operating costs, for a specific weekly maximum frequency of two flights, the A340-200 would be the least costly aircraft to use, while for a frequency of four flights the Boeing 737-400 would be the least costly choice.

### Route cost indicators

- Table 3 shows that in terms of cost of the service per aircraft-km, the cost to meet demand, the cost per hour utilised and the cost in terms of the average distance moved by the passengers (cost per pax-km), the least costly aircraft to run on the route is the Embraer 135 Jet.
- When looking at the indicators in terms of the ratio of cost per passenger-km to the cost of providing the service regardless of passenger numbers (cost per available seat-km), which is the load factor, the aircraft that fly at the highest load factor are the Boeing 747-200 and 767-300ER at a load factor of 0,99.

### Service indicators

- On analysing the work utilisation coefficient, which should be high, the Boeing 747-200 and 767-300ER are most favourable because of their high utilisation coefficient (load factor) of 0,99 in table 3, owing to fewer flights resulting from larger aircraft. On the other hand, if we look at the utilisation costs per aircraft-km, these particular planes are expensive to run for this route, costing US\$177 and US\$225 per aircraft-kilometre respectively. This implies that this load factor, a measure of profitability along routes, should be analysed after evaluating the operating costs of the aircraft. For exam-

Table 5 Cost per available seat-km for varying annual passenger numbers

Aircraft type	Embraer Erj-135-Jet	Boeing 737-200	Boeing 737-400	Airbus A320-200	Airbus A340-200	Boeing 737-800	Boeing 767-200	Boeing 747-200	Boeing 767-300ER	Boeing 747-400
For 30 000 annual passengers										
Annual costs (US\$) (000)	10 589	19 333	18 434	19 447	43 842	21 448	32 432	55 102	70 297	66 931
Available seat-km (ASK) (000)	92 352	101 400	104 832	112 320	92 040	117 936	119 340	90 792	90 480	125 216
Cost per ASK (US\$/seat-km)	0,11	0,19	0,18	0,17	0,48	0,18	0,27	0,61	0,78	0,53
For 60 000 annual passengers										
Annual costs (US\$) (000)	19 928	21 218	19 768	20 759	45 555	22 825	33 916	57 977	72 020	68 283
Available seat-km (ASK) (000)	184 704	182 520	183 456	196 560	184 080	206 388	198 900	181 584	180 960	187 824
Cost per ASK (US\$/seat-km)	0,11	0,12	0,11	0,11	0,25	0,11	0,17	0,32	0,40	0,36
For 90 000 annual passengers										
Annual costs (US\$) (000)	29 098	23 530	21 487	22 070	47 267	24 201	35 400	60 852	73 744	70 809
Available seat-km (ASK) (000)	271 284	283 920	288 288	280 800	276 120	294 840	278 460	272 376	271 440	313 040
Cost per ASK (US\$/seat-km)	0,11	0,08	0,07	0,08	0,17	0,08	0,13	0,22	0,27	0,23

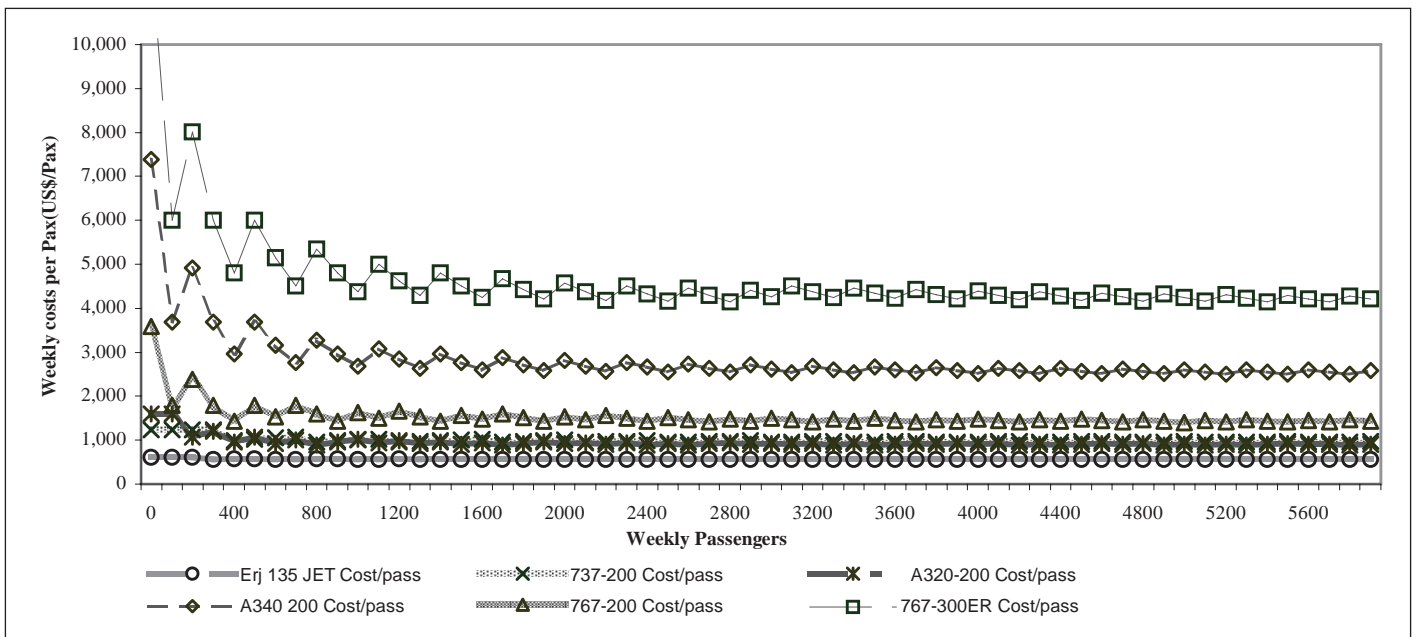


Figure 2 Operating costs per passenger for increasing passenger numbers

ple, the Boeing 737-200, which costs only US\$25 per aircraft-kilometre and has a relatively high load factor of 0,89, would be a better choice of aircraft for this route.

■ The service use intensity should also be high for the ratio of passengers travelling per aircraft-km flown to indicate that the service is being used optimally. This service indicator, like the work utilisation coefficient, should be considered after selecting the least costly aircraft based on operating costs. With this indicator the Boeing 737-200, 737-400, 737-800 and the Airbus A320-200 give satisfactory values.

Depending on the needs of the service provider in terms of cost, the following aircrafts are suitable in the specified parameters:

The above tables indicate that the Embraer 135 Jet is suitable for flying this route according to cost indicators. However, the limitations of flying this aircraft should be taken into account. For example, the ICAO stipulates that the maximum scheduled leg that the Embraer can fly is

2 600 km. Some service indicators may indicate otherwise, for example passengers not wanting to fly aircraft that are full, but the choice as a service provider in this industry is always dictated by cost parameters rather than service parameters.

### EFFECT OF VARYING PASSENGER DEMAND ON TYPE OF AIRCRAFT

Two of the characteristics of the airline industry are that passenger demand fluctuates according to the season, and passenger numbers increase by about 4% per annum. When selecting an aircraft for a route, the airline service provider therefore needs to consider how suitable the aircraft will be when passenger demand increases. The effects of passenger volume on the cost and service parameters for the 11 aircraft are discussed below.

### Cost per passenger

Doganis (2001), in explaining the effect of traffic density variations on cost, implies

that as passenger numbers increase, the cost per passenger should tend to follow a decreasing exponential curve, since the operating costs are spread over more people using the service. Figure 1 was obtained from plotting the respective operating costs per passenger flying versus increasing passenger demand. It shows that the general trend of operating costs decreases exponentially as the traffic density on a route increases.

■ Again we see that the Embraer ERJ-135-JET is the least costly – below 50 pax/week at about US\$700 per pax, which evens out to about US\$600 per passenger as passenger numbers increase.

■ After a weekly passenger demand of 300 passengers per week, the least costly aircraft for the passengers are the Boeing 737-200 and the Airbus A320-200, whose costs per passenger remain fixed at about US\$450.

■ The discontinuities in the curves mean that at that point the existing fleet size

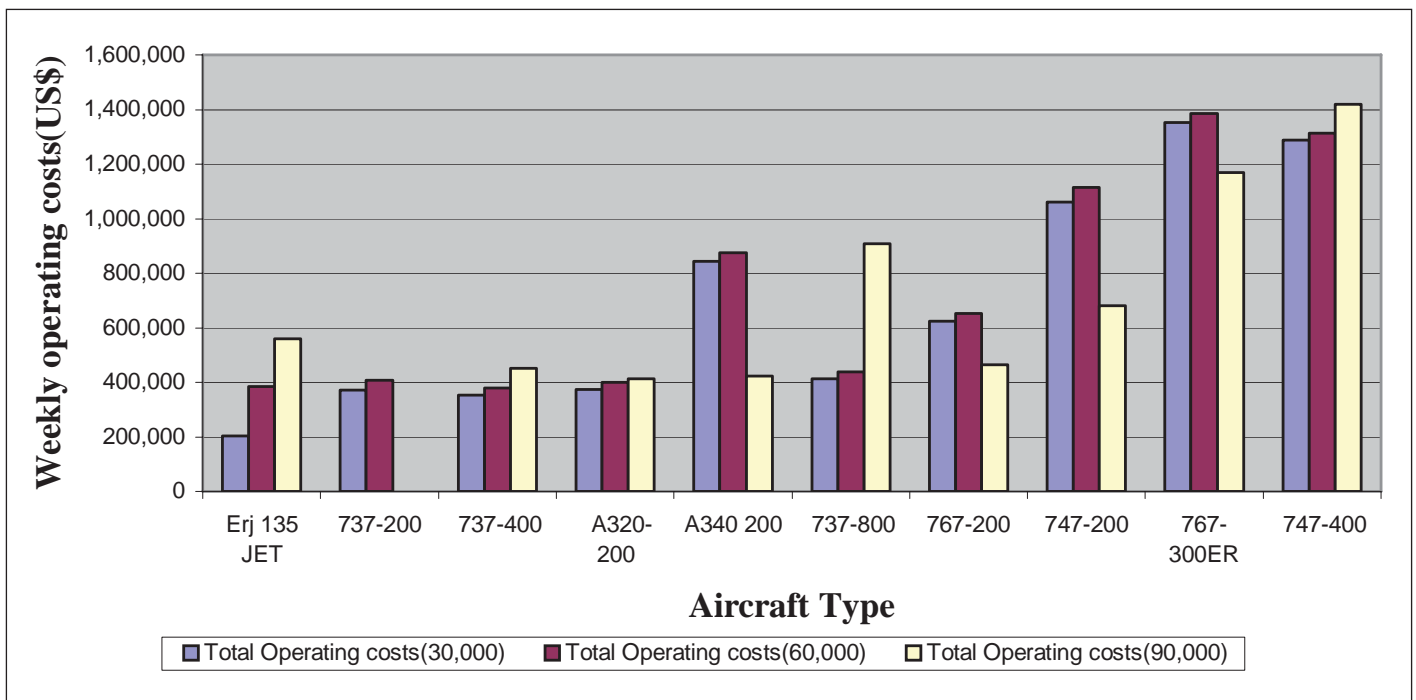


Figure 3 Weekly route operating costs for different passenger numbers

needs to be increased to meet passenger demand. That is, there is an increase of US\$1000/pax for the Boeing 767-300ER between 250 and 300pax/week, because an extra aircraft is added to the service.

- As the passengers increase, the cost per passenger reduces gradually. See how the discontinuities in the Boeing 767-200 even out as passenger demand increases.

### Cost per available seat-kilometre

The cost per available seat-kilometre is a crucial indicator since it is a measure of the cost of providing the service.

- In table 4 the Embraer Erj 135-Jet costs per available seat-km do not change with varying passenger demand.
- For the other types of aircraft, the cost per available seat-km tends to decrease as passenger numbers increase. It is interesting to note that for a demand of 60 000 annual passengers, the cost of providing the total quantity of service is the same for a 37-seater aircraft as it is for larger aircraft with a seating capacity of 160–180. This could be as a result of the smaller cheaper aircraft having to fly at higher frequencies to meet passenger demand.

### Total operating costs

This gives a measure of how the operating costs of an aircraft vary as passenger numbers increase. The annual operating costs calculated in table 4 are plotted in figure 2 to show the general trend, which should be that as the passenger demand increases, the frequency of flights also increases. This will have an impact on fleet size, since the maximum number of flights a single aircraft may make cannot be exceeded. Airlines sometimes opt for larger aircraft when passenger demand increases, but this is only a cheap

option for routes that fly at greater capacity in peak season. For example, on the Cape Town–Johannesburg route, the increased operating costs are spread over the doubled passenger demand. Second, it is always easier to increase aircraft size, since increasing frequency will take the airlines back to the negotiating table for more slots.

- Figure 2 shows the general trend of operating costs increasing with increasing passenger numbers. For the smaller aircraft, the Embraer Erj135-Jet, fleet size has to increase markedly to accommodate increasing passengers, while for the larger aircraft the available fleet size can meet demand by increasing flight frequency.
- Aircraft such as the Airbus A320-200 and the Boeing 737-400 and 732-200 are suitable choices for routes with unpredictable passenger demand, since the operating costs are quite low and do not vary significantly, even when passenger numbers increase.

### AIRCRAFT SELECTION LIMITATIONS

From these factors we see that the Embraer ERJ-135 JET, Airbus A320-200, the Boeing 737-400 and 732-200 are the most suitable aircraft for this route. However, factors other than cost may affect the selection of an aircraft, for example:

- **Range:** Even though the Embraer Erj 135-Jet has the lowest costs, its maximum range is 3 019 km, which is also dependent on varying conditions such as take-off altitude, wind speed and load. This therefore makes it a risky choice for the above route of 3 000 km. In emergency procedures, when the aircraft must remain longer in the air, according to minimum fuel load and diversion capacities required

by ICAO, the risk of it running out of fuel is high.

- **Slots:** For airports that suffer from congestion, airport authorities may dictate the number of slots a week that are assigned to a certain airline. To maximise these slots, larger aircraft will be used for the route to meet the existing passenger demand.
- **Competition:** This is the biggest asset airlines offer their target market, in order to maintain and increase the number of passengers using their service. Some of the reasons that types of aircraft are determined by competition include their target market under the following considerations:
  - The purpose of travel either business, holiday or leisure
  - The cost of travel versus convenience in terms of time due to hubbing
  - The quality of service expected, that is, the comfort and service expected (first class versus business or economy class)

To attract passengers, airlines are forced to fly aircraft to meet their target market so as to compete with other airlines flying the same route. For example, the Boeing 737-200 is a cheap aircraft to fly, but is outdated in terms of the services it provides the passengers.

### CONCLUSIONS

The aim of this paper was to apply a recently developed operating cost model to aircraft commonly used in Africa for short-haul routes in terms of cost-related parameters. The model was used to investigate how appropriate aircraft choice can be used to minimise route-operating costs when meeting specified levels of service.

The model was able to calculate the cost parameters incurred while supplying a transport service that allowed the user to make an informed choice in terms of the total cost, the operating cost and aircraft utilisation and also to take into account varying passenger demand. Owing to the number of assumptions in the model, the results are useful in relative terms, but not necessarily in absolute terms.

The operating costs incurred for short-haul distances of less than or equal to 3 000 km and annual passenger demand of fewer than or equal to 50 000 passengers are much lower for smaller aircraft such as the Embraer Jet and the Fokker. These route characteristics constitute about 70% of the Africa route network and would therefore benefit greatly from the use of the smaller aircraft as a strategy for lowering operating costs.

The load factor of an aircraft, which is a measure of profitability along a route, has to be analysed together with the costs of utilising the aircraft, because high load factors can be achieved with larger aircraft, which

fly at lower frequencies to meet the same demand, but with high utilisation costs.

Because passenger numbers vary, cost-related parameters were analysed to show that the model confirmed the general exponential trend of costs per passenger becoming lower for increasing passenger demand.

The aircraft used in the market today may not necessarily be the least costly ones because factors such as the available airport slots, maximum range for specific aircraft and competition between airlines may dictate the aircraft to be used on a given route.

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