# DEVELOPING A COST MODEL FOR RUNNING AN AIRLINE SERVICE

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## ABSTRACT

**From the NEPAD objective of partnership in the African continent, major connectivity within Africa as should be addressed through air transport. The paper involves, describing the nature of the airline industry, especially in the African situation with some of the issues being high airfares and poor accessibility within the continent. In order to address these problems however, an analysis of the minimal operating costs and key factors affecting route costs is carried out. The aim of the paper was to develop from first principles, a cost model to calculate operating costs along any route in the African continent and test its applicability.**

**The costing of an airline service is reviewed through existing literature and a compilation of the structure, components and their equations and default values done. A model structure to calculate these operating costs on a route is set up, while data is analysed to provide databases and calculations to the model. The model is then calibrated by comparing costs calculated with fares of a given route within Africa, showing its applicability while proposals for further research in hubbing to consolidate traffic as a method of minimising costs for airlines.**

## 1. INTRODUCTION

### 1.1 Background

The New Partnership for Africa's Development (NEPAD) objective is a pledge by African leaders, based on a common vision with a firm and shared conviction, of a new relationship of partnership in Africa as a continent. Its objective is to give impetus to Africa's development by bridging existing gaps in priority routes in order to enable the continent to catch up with developed parts of the world (NEPAD report, 2002). The field to be addressed in light of the above objective is the airline industry in Africa

The airline industry worldwide has been going through some significant changes. These were mainly brought about by the fact that historically airlines were being run by governments, but due to a lack of funding they have been privatized (AFRAA, 1999). 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. Because of the above financial and management problems, privatization of airlines has been adopted but with only a few successes. There are few investors interested in airlines, which continually operate at a loss.

### 1.2 Problem Statement

There are many problems facing the African airline industry, high airfares, long travel times as airlines consolidate passenger traffic, inaccessibility within different parts of the continent.

From the NEPAD objective of improving accessibility within the continent, these questions need to be addressed:

- What is the basic minimum cost for providing an airline service on a given route? Can the airfares on the market equally representative of this basic operating cost, sector length and passenger demand?
- Can the operating costs for a route be designed optimally, such that the basic service is provided, moving air passengers from their origin to destination, without compromising on the extra distances travelled?

1.3 Aim of Paper

In light of the above issues, a model will be developed to calculate the cost of an airline service. This model will be developed from existing cost structures to calculate the operating costs of running this transport service along any given route for the African continent.

1.4 Limitations

A route cost model based on literature on the cost structure of airlines, available data on equations, default values, existing passenger volumes and sector distances.

Degrees of freedom, airport capacities, time slots, environmental issues on noise and pollution, and the politics surrounding the airline business, will not be considered.

The airline service being considered is a traditional passenger airline transporting passengers to their destinations. It is therefore not a specialized modern airline i.e. either a low cost carrier, freight carrier, etc.

## 2. MODEL DEVELOPMENT

2.1 Cost Structure

Doganis (1989) states that the costing of an airline service is an essential input to many decisions taken by airline managers, as to whether to run a service along a given route or whether the service will be making money or not. The way the costs are broken down and categorized will depend on the purpose for which they are being used.

The operating costs of airlines are divided into operating and non-operating items, to distinguish the latter as the costs and revenues not directly associated with airlines' own air services. The operating items are then further divided into direct and indirect operating costs, where the former include all costs that are dependant on the type of aircraft being operated and the latter, all the costs that have to be incurred irrespective of the aircraft type.

For this model, only the operating items were considered and sub divided under the following: standing (capital) costs of the aircraft, the flying costs as a result of utilisation of the aircraft and other costs that are incurred while running service. The cost structure that will be adopted for the model is summarised in Figure 1.

The operating cost component equations that will be used in the model are classified as standing, flying and other costs. The equations to be used in the model are given in Table 1.

The following assumptions were made in developing the cost component equations:

- The data that has been collected has been found to be valid and referenced accordingly.
- Calculations for the direct operating costs, which include standing and flying costs, are calculated in the rate of hours utilized annually, while the other costs are calculated as per unit description.

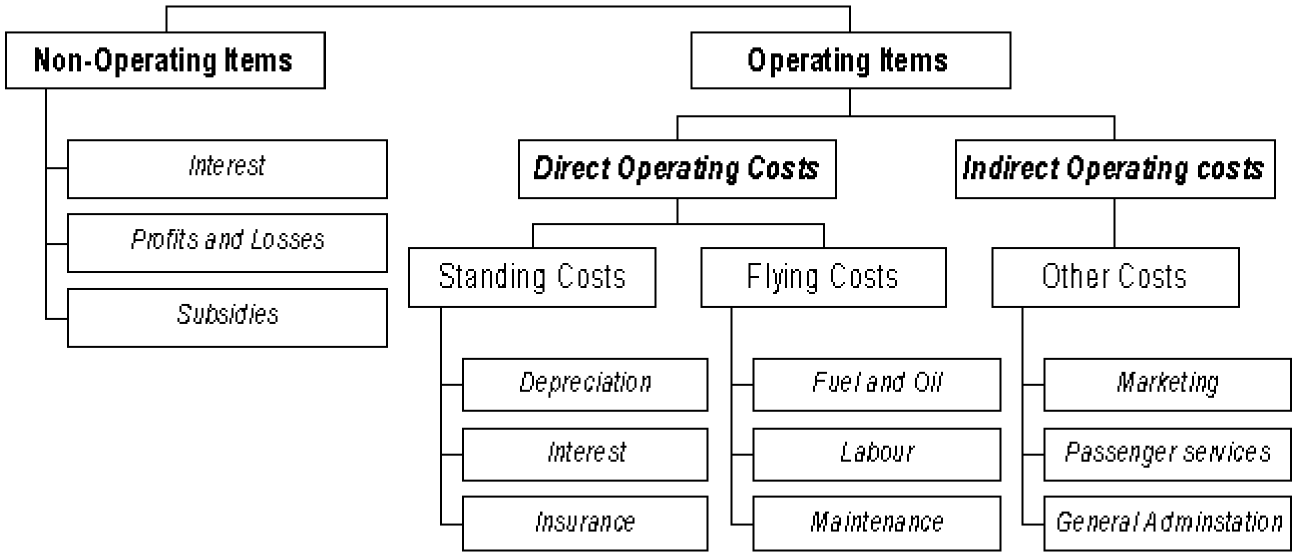


**Figure 1. Cost structure adapted for model.**

2.2 Standing Costs

2.2.1 Depreciation

Depreciation is defined as the charge an airline incurs for the expense for the flight equipment losing its value over time. The cost of depreciation per hour ($C_{Dep}$) can be calculated using the linear depreciation function Equation 1 from Stratford (1973). The hourly depreciation cost of each aircraft in any one year can be established by dividing its annual depreciation cost by the aircraft annual utilisation.

$$C_{Dep} = C_{total}\,(1-r_v)/L * U \tag{1}$$

Where $C_{total}$ = Total cost of aircraft, engine and equipment

$r_v$ = Residual value as a proportion of the fully equipped aircraft and spares after the assumed life period (L years).

U = average utilisation per aircraft in revenue block hours/year

2.2.2 Insurance

Insurance is an annual amount of money paid each year, in case of any risks that may be incurred to the aircraft during its service life. These include fire, hijacking, theft, etc. Doganis (1989) states that the insurance premium paid by an airline for each aircraft is calculated as a percentage of the full replacement price. The annual premium may range between 1,5-3% depending on a number of factors including; the airline, the number of aircraft it has insured, and the geographical areas in which the aircraft operates. Stratford (1973) shows that the cost insurance per hour ($C_{Ins}$) on the total cost of equipped aircraft and spares, at a rate of x percent, and annual utilisation U is given by:

$$C_{Ins} = (x * C_{Total}) / U \tag{2}$$

Where: $C_{total}$ = Total cost of aircraft, engine and equipment.

x = Annual insurance premium rate

2.2.3 Interest Rate

Interest rate is simply defined as the cost of borrowing money; it is given as a percentage value that is applied to the outstanding loan. The airline industry being highly capital intensive means that this component should be included. The interest rate is set depending on the economic conditions i.e. inflation; bank lending rates, forex rates, etc in the country where the loan is acquired. Since this study is cutting across various countries with widely varying economic conditions, an interest rate chosen should be representative of majority of the African countries, i.e. the rate at the World Bank lends money, taken as 8%.

## 2.3 Flying Costs

### 2.3.1 Fuel and Oil

Doganis (1989) states fuel as another major element in the cost of flight operations The amount of fuel used up at the block time, is given in terms of volume (US gal/hr) and varies at climbing, descending and cruising. Fuel consumption is determined by; engine thrust, Specific fuel consumption (SFC), and the number of engines for each of these maneuvers. The volume of oil is also calculated per block hour at a ratio of 1:20 to the volume of fuel. The ATA (1963) formula for calculating cost of fuel and oil per block hour is used below, assuming the factor 1.02 in Equation 3 caters for the 2% factor of reserve fuel, needed in emergencies.

$$C_{ah} = 1{,}02\ (V_f * C_{ft} + 0{,}\ 135 * C_{ot} * V_o) \qquad (3)$$

Where: $V_f$= Block fuel volume (US gal/hr)
$C_{ft}$ = Cost of fuel per US gallon
$C_{ot}$ = Cost of oil for turbine engines per quart
$V_o$= Block oil volume (US gal/hr) = (1/20) * $V_f$

### 2.3.2 Maintenance

The term "maintenance" as presented in the ATA method includes labour and material costs for inspection, servicing, and overhaul of the airframe and it's accessories, engines, propellers, instruments, radio, etc. The relationship between the costs of components from Department of Transport (US) (Kane, 1996) and ICAO (Doganis, 1989) reflects that insurance and maintenance amount to an average of about 2,5% and 9,8% respectively of the total operating cost of an airline service. This percentage ratio between insurance that is easily calculated, will be used to obtain the value for maintenance.

### 2.3.3 Crew Costs

The flight crew costs include all costs associated with the flight and cabin crew including allowances, pensions, salaries, etc. They usually are the largest element in operating expenses. In 1963, the ATA derived costs from a review of several representative crew contracts; based on speed and the ToGWmax the equation is converted to metric units for this study and is shown in Table 1.

**Table 1. Crew costs per hour (US$/flight hour).**

| Engine Type | International Planes |
|---|---|
| | Three-man crew |
| Turbo Jet | [0,0000225ToGWmax + 200] |
| | For each additional member |
| | + [35] |

## 2.4 Other Costs

### 2.4.1 Landing and Parking Fees

Stratford (1973), states that these fees are included as an operating expense and are of significance in actual and comparative aircraft cost estimates. Landing fees are based on the gross weight of the aircraft, but a number of exceptions to this exist and international flights and short sector flights are in some cases liable to special rates for landing fees. Parking fees are also charged depending on the weight of the aircraft per 24-hour period, after a specific time period.

2.4.2 Passenger Fees
Doganis (1989) states that airport charges include a passenger charge for handling relating to the number of passengers disembarking from an aircraft. Most airports presently collect a fee directly from the passengers, termed the airport tax and are included in the fare paid by the passengers.

2.4.3 Ticketing, Sales and Commission
Doganis (1989) relates the sales, ticketing and promotion charges to those engaged in ticketing sales and promotion activities as well as all office and accommodation costs arising throughout these activities. Doganis (1989) shows that the percentage of costs that are allocated to ticketing, sales and commissions, amount to 15,5% of indirect operating cost. The ratio of percentages of ticketing, sales (15,5%) to direct operating costs (58,4%) is used to calculate the item.

2.4.4 General Administration
Doganis (1989) gives the percentage that administration contributes to 6,1% of airline indirect operating costs. The ratio of percentages of general administration (6,1%) to direct operating costs (58,4%) will be used to calculate the cost for general administration

## 3. MODEL DESCRIPTION

Figure 2 shows the flow chart that comprises of the model developed from first principles. It gives the layout of the calculations to be done and what information is required as input to give the output data necessary and service analysis.

3.1 The Input Component
All the data that serves as input to the model is included in the sheet. The user of the model can input the basic descriptors of the route, for which the operating costs to be calculated. The user of the model 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 databases 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***.

3.2 The Calculation Component
The purpose of this sheet is to calculate the cost components, for each of the 11 aircraft types, for the particular route. Most of the cost components 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, ***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 meet existing demand. Once the utilisation, fleet size and block time for the route has been calculated, each of the ***costs components*** are then derived using the default values, equations and aircraft specifications for each aircraft type.

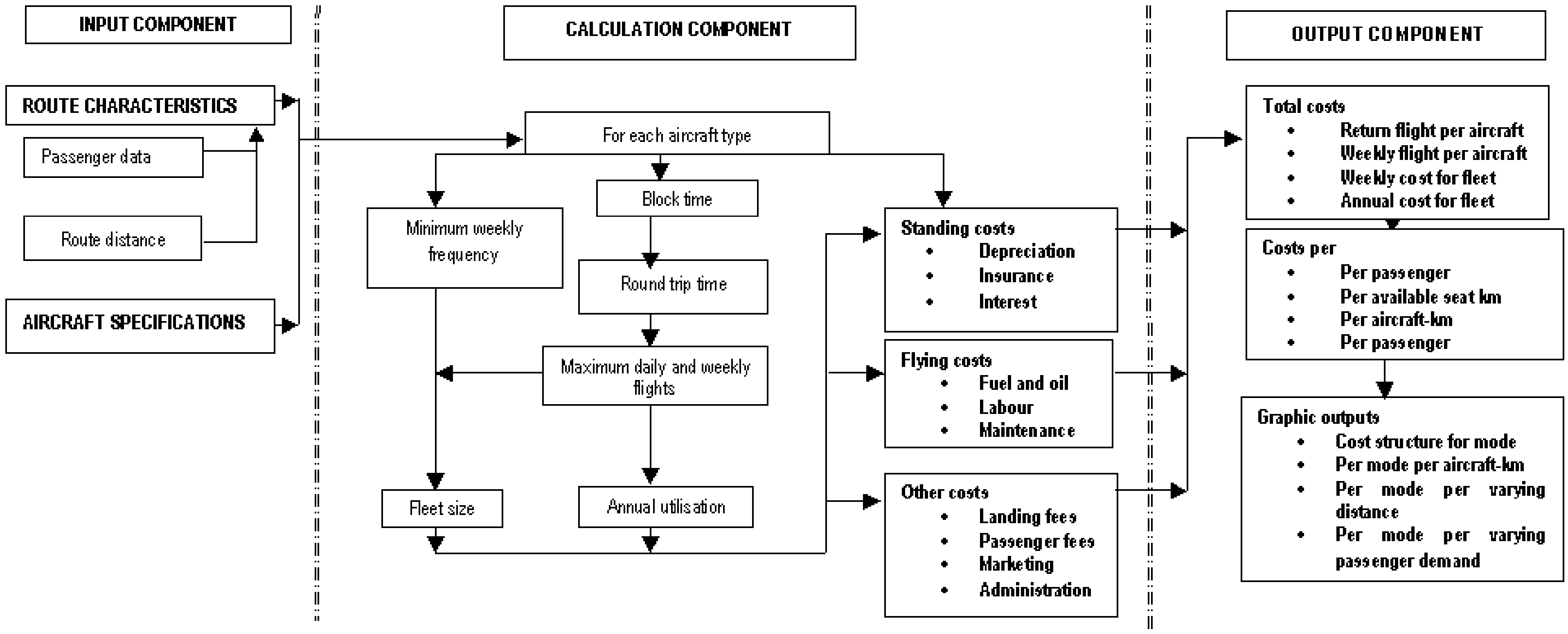


**Figure 2. Model flow chart.**

3.3 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 different 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.

## 4. DATA COLLECTION

This chapter is a compilation of all data that is used in developing the cost model. The default values that have been compiled from references are shown in Table 2. The second set of this section compiles with the external data needed for the paper and the sources used.

4.1 Default Values

The values used in the model are collected in the table 3 below and are referenced accordingly;

**Table 2. Default values used in the model.**

| ITEM | DEFAULT VALUES | REFERENCE |
|---|---|---|
| Depreciation period (L) (years) | 9 | Doganis (1989) |
| Residual value ($r_v$) (%) | 10 | Doganis (1989) |
| Interest rate (%) | 8 | World Bank (2003) |
| Insurance rate (x) (%) | 2 | Doganis (1989) |
| Ground manoeuvre time (hrs) | 0,25 | ATA (1963) |
| Air manoeuvre time (hrs) | 0,10 | Kane (1996) |
| Service and refueling time (hours) | 0,90 | Kulula airlines (2003) |
| Usable hours in a day | 14 | Stratford (1973) |
| Operating weeks in a year | 52 | Stratford (1973) |
| Cost of fuel (US$/US gal) | 0,895 | Emery (2002) |
| Cost of oil (US$/quart) | 0,233 | Turbo jet technologies (2003) |
| Average international air passengers moving within Africa region (%) | 15 | AFRAA (2000) |

4.2 Aircraft Type Specific Data

The model deals with 11 types of aircraft, commonly used for airlines within Africa. In order to calculate the cost of running the chosen aircraft, technical specifications necessary are collected from sources shown in Table 3.

**Table 3. 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/hr) | Rolls Royce (2003) |
| Oil consumption (US gal/hr) | 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) |

## 5. AFRICA ROUTE NETWORK

The cost model developed will be applied to the Africa network. This model can be used to build the conventional steps in the transport-planning model to obtain trip generation and trip distribution to get O-D passenger data. The model requires input databases for distances and passengers for each O – D pair within Africa to calculate the costs of running a service along any of these routes.

### 5.1 Trip Generation

The model will be based on airports within the African continent therefore country specific data relevant to this paper is needed. 50 countries represented by 1 major international airport per country within the continent will be used to generate the trips specific to air travel. IATA airport identification codes are obtained for these airports, then a 50x50 origin- destination passenger and distance matrix will be developed.

#### 5.1.1 Distance Matrix

The one-way distance between each of these airports is collected from the same website with an online mileage calculator in which the origin and destination codes serve as input to provide to air distance in the user's choice of units. This was done for each of the airports to create a 50 X 50-distance matrix in km.

#### 5.1.2 O – D Passenger Matrix

World Bank data query is an online database that provided information on development indicators for World Bank member countries. Indicators relevant to this study collected include; population, GDP (US$) and aircraft departures/year, for the year 2001.

The aircraft departures are multiplied by a factor of 15%(AFRAA, 1999) to calculate the aircraft departures moving only within Africa. Passenger numbers are calculated from the product of aircraft departures and an average aircraft seat capacity assumed to be 200. The O-D trips are developed using the Furness method for a doubly constrained matrix. The cost matrix used is assumed to be proportional to the distance between each O-D pair assuming a $\beta$ be 0.14,an average aircraft speed of 800km/hr and $\alpha$ was calculated to be 52.02.

### 5.2 Model Application

With all the input data for the distance and costs for all routes in Africa, a route network can be created. This means for a route, application of the O-D pair specific passenger numbers and distances, the cost of running the service for 11 aircraft types and service parameters such as fleet size and frequency computed.

**Table 4. Most efficient aircraft for EBB-JNB route.**

| Parameters | Erj 135-JET | B737-200 | B737-400 | A320-200 |
|---|---|---|---|---|
| Minimum weekly flights to meet demand | 17 | 5 | 4 | 4 |
| Cost per aircraft-km (US$/ aircraft-km) | 4 | 25 | 30 | 32 |
| Cost per passenger assuming full capacity (US$/pass) | 328 | 571 | 527 | 519 |
| Cost per passenger flying (US$ / pass) | 344 | 620 | 591 | 624 |
| Cost per available seat km (US$ / ASK) | 0,11 | 0,19 | 0,18 | 0,18 |
| Cost per passenger-km (US$ / pass-km) | 0,12 | 0,21 | 0,20 | 0,21 |
| Cost per hour utilised (cost / hr) | 3 007 | 16 986 | 21 543 | 23 169 |
| Weekly aircraft Efficiency (aircraft-km/aircraft) | 50 014 | 14 710 | 11 768 | 11 768 |
| Weekly service use intensity (pass/Aircraft-km) | 0,0120 | 0,0407 | 0,0509 | 0,0509 |
| Weekly Aircraft fleet Utilisation (aircraft-hrs/aircraft) | 68,54 | 21,86 | 16,44 | 16,13 |
| Work utilisation coefficient (pass/seat) | 0,95 | 0,92 | 0,89 | 0,83 |

The model was applied to the route Entebbe, Uganda and Johannesburg, South Africa that has 599 weekly passengers with a route length of 2 942km, according to the databases. Table 4 is a compilation of the data for the four least costly aircraft that can be used on this route according to the model results. This will be used to test the model's applicability to the present situation. Presently the airlines that run this direct route include: South African Airlines (SAA) thrice weekly using the Airbus A320-200 and East African Airlines (EAA) twice weekly using the Boeing 737-200. The average airfare is US$ 600 for a return ticket on this route.

According to the results from the model seen in Table 4 the following can be deduced:

- The Embraer Erj135-Jet is obviously a more economically efficient aircraft to run but the Boeing 737-200 will be a better choice because of the maximum ranges each aircraft can fly. The farthest distance an aircraft can fly without re-fueling dictates the maximum range of an aircraft. Embraer Erj135-Jet has a maximum range of 3 019km as compared to the Boeing 737-00 whose range is 3700km. This makes Boeing 737-200 a safer choice in case of an emergency in situations where air traffic is high and the aircraft need to stay in the air longer, before landing at the destination airport.
- The work utilisation coefficient, which is the load factor at which the aircraft would fly this route based on the existing passenger demand. This load factor is defined as the percentage of the aircraft that must be filled by passengers in order for the airline to cover direct operating costs for a flight. The higher the load factor, the more favorable the route to break-even using the supply and demand for the route, especially when the costs per hour utilised are low. For this route, the load factor of the Embraer Erj135-JET and the Boeing 737-200 aircraft are quite good.
- The choice of aircraft being used on the market today B737-200 and A320-200 is amongst those with the least operating costs as calculated in the model. The costs for available demand: per passenger (at existing demand), costs at 100% capacity and costs of supplying service: per hour utilised, per aircraft and available seat kilometres in Table 4 are quite low, implying that for the existing passenger data and sector distance according to the model, the aircraft used are a good choice. The aircraft being used in the market today, may not necessarily be the cheapest ones because in the industry, other factors like the airport slots, maximum range and competition between airlines, may dictate the aircraft to be used on a given route.
- Indicators reflecting the service being provided, in terms of aircraft efficiency and aircraft fleet utilisation and service use intensity, the higher the indicator value, the more favorable the service. These determine whether the service is being used optimally.
- The costs per passenger given by this model are not representative of the air fares charged for this route. This could be because, the model does not take into account factors like competition and the politics surrounding the frequency and due to unavailability of data assumptions made in equations and default values used may be outdated or out of context for the African situation.

## 6. CONCLUSION

### 6.1 Results

The purpose for this paper was to develop a model that would be able to estimate the cost of an airline service along a given route, within Africa region.

- A cost structure, equations and default values were collected from various literature sources and focus was put on the operating items which where divided into the standing, flying and other costs.
- The model developed was able to calculate the cost parameters incurred while supplying a transport service allowing the user can then make an informed choice on: least costly aircraft type, lowest operating costs, highly utilised fleet size, economically efficient service, varying passenger demand. Due to the number of assumptions in the model, the results are useful in relative terms but not necessarily in absolute terms.

- In order to summarise whether this paper has addressed the problems, the model was applied to a route Entebbe, Uganda and Johannesburg, South Africa. Results showed how the costs and service indicators calculated by the model and aircraft types used can be used to analyse the service provided on the market today.
- Generally, smaller aircraft were found to have much less operating costs, than larger aircraft making them cheaper to run even when passenger demand is reasonably high, since their costs incurred even for higher frequency of flights is still much less than larger aircraft. This is found in the aviation industry today, to be the basis of low-cost air carriers, and could be a viable option to consider by consolidating passenger traffic on shortening routes by design of a hub and spoke network, within Africa.

In conclusion, the cost model, developed can be used to address and analyse issues concerning analysis of air services along routes within Africa as has been shown above. Because of the number of assumptions in the model, the results are useful in relative terms, but not necessarily in absolute terms.

6.2 Recommendations

From the study done it is recommended that:

- More up-to-date cost component equations and default values should be drawn up in the aviation industry. Most of the equipment, economic market prices and technology used to cost airline services has changed over the last two decades and therefore newer more generalized equations or default data need to be developed, for this ever changing field.
- Civil aviation authorities, airlines, and airport companies, create, compile and update databases for the air passenger traffic, to assist further research into the field.
- The model default values, i.e. discount rates, annual insurance rates, depreciation periods, lost times, be updated for the ever changing economic and political conditions that are a big problem faced by the airline industry
- Further study and research need to be done to the model, in its application of creating a hub and spoke network within Africa to consolidate passenger traffic, and shorten routes in a bid to lower operating costs.

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