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DEVELOPING A COST MODEL FOR RUNNING AN AIRLINE SERVICE

SSAMULA BRIDGET

A dissertation submitted in partial fulfillment of the requirements for the degree
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SUMMARY

DEVELOPING A COST MODEL FOR RUNNING AN AIRLINE SERVICE

SSAMULA BRIDGET

Supervisor:	Professor R. Del Mistro
Department:	Civil and Biosystems Engineering
University:	University of Pretoria
Degree:	Master of Engineering (Transportation engineering)

There are many problems facing the African airline industry, from high airfares to unnecessarily long travel times necessary for airlines to consolidate passenger traffic. From the NEPAD objective of improving accessibility within the continent, the following questions need to be addressed:

1. What is the basic minimum cost for providing an airline service on a given route?
2. Can the airfares on the market equally representative of this basic operating cost, sector length and passenger demand?
3. 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, for example by choosing smaller cheaper aircraft for shorter routes?

The purpose of this study was to develop a model that would be able to estimate the cost of an airline service and analyse service level along a given route, giving various aircraft technical specifications and data relevant for different components of the cost structure.

Collecting literature necessary to understand route economics initiated the study, in the following areas:

- The costing structure of the airline service and its components.

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- The information of the various components contributing to the cost including: equations, default values, technical data etc.
- Understanding the different aspects of the airline industry that affect the costs i.e. aircraft type, passenger demand, route competition, etc.

This was then narrowed down to the components of the cost structure to be focused on in the study. A review of the airline industry was done from available literature, giving insight to the operating cost components and the key determinants or indicators, which affect the operating costs.

The structure of the model was developed using the operating cost components to calculate the cost of running an airline service along a route. The cost structure adopted and the relevance of components was outlined.

The data from specified sources relevant in order for the model to compute the costs was collected and applied. In situations where the data was lacking, assumption and explanations were given. Model default values that were compiled and deemed necessary were chosen and justified, in light of their applicability to the model situation.

The results of the model were then used to analyse the route operating costs, suitable aircraft options and service analyses. Trends, graphs and tables were used to explain the above analyses, in terms of cost effectiveness, quality of service and aircraft choice. The model was then used to analyse the effect of the input components of distance and passenger number on; fleet size, operating costs and other aspects of the airline service.

Finally it was shown how the cost model could be applied to the analysis of route options for Africa (including trip generation, distribution and hubbing in which further research is required). Because of the number of assumptions in the model the results are useful in relative terms, but not necessarily in absolute terms. It compiles the operating costs and can be used to design an optimum transport service for any route within Africa.

Key words: African airlines, cost structure, operating costs components, cost model, aircraft types, passengers, sector distance, fleet size, route cost analysis, service indicators.

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ABSTRACT

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The study involves, describing the nature of the airline industry, especially in the African situation with some of its problems being high airfares and inaccessibility within the continent. In order to address these problems an analysis of the minimal operating costs and challenging factors affecting route costs needs to be carried out. The aim of the study was to develop from first principles, a cost model to calculate operating costs along any route in the African continent. The costing of an airline service is reviewed through existing literature and a compilation of the structure, components and their equations and default values was done. A model structure to calculate these operating costs on a route is set up, while data is analysed to provide inputs to the model. The model is then applied to carry out an analysis of the type of service provided in terms of costs and service quality. Africa specific data is then included in the model in terms of passenger trips and sector distances and these are embedded into the model The main conclusion drawn from the study was that this model could be used to design optimally an airline service based on operating costs using existing passenger demand and sector distance. The model was applied to a route within Africa and results showing how smaller capacity aircraft even though limited by maximum range are the most economical to run along routes when the frequency of flights is high.

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d) The following persons; Jenny Gray, Sibusiso Mdlalose and Emmanuel Olekambainei, who introduced me to the ins and outs of the airline service industry in spite of all its political hiccups

DECLARATION

I the undersigned do declare that the work that has been written and produced, is my own work, all work that has been quoted, is referenced, accordingly.

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LIST OF SYMBOLS

ACSA = Airports Company South Africa

ASK = Available seat-km

ATA = The Air Transport Association

A320-200 = Airbus A320-200 Aircraft

A340-200 = Airbus A340-200 Aircraft

B737-200 = Boeing 737-200 Aircraft

B737-400 = Boeing 737-400 Aircraft

B737-800 = Boeing 737-800 Aircraft

B747-200 = Boeing 747- 200 aircraft

B747-400 = Boeing 747-400 aircraft

B767-200 = Boeing 767-200 Aircraft

B767-300ER = Boeing 767- 300ER Aircraft

C_{air} = Cost of one furnished airframe with spares (US$)

C_{am}= Cost per air mile

C_{eng} = Cost of the engines installed in one airframe, and the spare engines together with the engine spares holding per airframe. (US$)

C_{equ} = Equipment (including radio and radar) installed together with the spares holding of equipment per airframe. (US$)

C_{ft} = Cost of Fuel per US gallon (US$/US gal)

C_{ct} = Cost of oil for turbine engines consumed per flight hour (US$/quart)

C_{ins}= Cost of insurance (US$)

C_{sd} = Cost per hour of the depreciation of the flight equipment (US$).

C_{total} = Total aircraft cost including engines (US$)

D = Serviceable operating days in the year

Erj 135 JET = Embraer Erj 135-Jet aircraft

F_{am} = Six minutes at best cruise procedure consistent with airline practice (no credit for distance), to allow for cruise (US gal)

F_b = Block fuel (US gal)

F_{cl} = Fuel to climb to cruise altitude. (US gal)

F_{cr} = Fuel consumed at cruise altitude (US gal)

Fd = Fuel required to descend including deceleration to normal approach speed. (US gal)

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F_{gm} = Ground manoeuvre fuel (US gal)

F50 = Fokker F50

GDP = Gross Domestic Product

GNP = Gross National Product

H = Usable hours in the operating day

ICAO = International Civil Aviation Organisation

IATA = International Air Transport Association

IRa =Rate/US$ value (%)

K_a = Airway distance increment

L = Depreciation period (years)

n = Number of flights per day

N_e = Number of engines

NEPAD = The New Partnership for Africa's Development

R = Mean distance per route

R_c = Distance to climb plus distance to accelerate from takeoff speed to climb speed. (Statute miles)

R_d = Distance to descend including distance to decelerate to normal approach speed. (Statute miles)

R_L = Labour Rate (US$/block hour)

RPK = Revenue Passenger-km

r_v = Residual value as a proportion of the fully equipped aircraft after the assumed life period (%).

SFC = Specific Fuel Consumption

T = Maximum Certificated takeoff thrust (Ibf)

T_{am} = Time for air manoeuvre (min)

T_b = Block time (hours)

T_{cl} = Time to climb including acceleration from takeoff speed to cruise speed (min)

T_{cr} = Time at cruise altitude (including traffic allowance)(min)

T_d = Time to descend including deceleration to normal approach speed (min)

t_f = Flight time (hours)

t_g = Average ground time at transit and terminal points

T_{gm} = Ground manoeuvre time in hours including one minute for takeoff (min)

t_l = Average time lost during take-off, climb, and descent and taxi time

ToGWmax = Maximum certificated take-off Gross Weight (Kg)

U = Average utilisation per aircraft in revenue (block hours/year).

V_b = Average block speed of the aircraft (km/hr)

V_{cr} = Average true airspeed in cruise (mph)

W_a = Basic Empty Weight of the Aircraft Less Engines (Kg)

X = Annual insurance premium rate (%)

DEFINITIONS

Aircraft-km is the distance flown by an aircraft which is obtained by multiplying the number of flights performed on each flight sector by the sector distance.

Aircraft utilisation is the average number of block hours that each aircraft is in use. This is generally measured on a daily or annual basis.

Available seat-km (ASKs) obtained by multiplying the number of seats available for sale on each flight by the flight sector distance.

Average aircraft capacity is obtained by dividing an airline's total available tonne km (ATKs) by aircraft-km flown.

Average sector length is obtained by dividing an airline's total aircraft-km flown in a year by the number of aircraft departures; it is the weighted average of sector/sector lengths flown by an airline.

Block time (hours) is the time for each sector flight or sector, measured from when the aircraft leaves the airport gate or stand (engine on) to when it arrives on the gate or stands at the destination airport (engine off). It can also be calculated from the moment an aircraft moves under it's own power until it comes to rest at its destination.

Break-even load factor (percent) is the load factor required to equate total traffic revenue with operating costs.

Block speed (km/h) is the average speed at which an aircraft will fly over a given sector. It usually takes into consideration the cruising, take-off and the landing speed.

Cabin crew refers to stewards and stewardesses.

Degree of Freedom this is a privilege that is given by one country to another before it can fly in and out of the country, or even before it can fly over a country before landing. These degrees range from the 1st the 8th degree of freedom, depending on the agreement between the countries.

Flight or cockpit crew refers to the pilot, co-pilot and flight engineer

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Length of passenger haul the average distance flown by an airline's passengers. This is obtained by dividing the airline's total passenger-km by the number of passengers carried

Operating costs per Available Tonne Kilometre (ATK) is a measure obtained by dividing total operating costs by total ATKs. Operating costs exclude interest payments, taxes and extraordinary items. They can also be measured per Revenue Tonne Kilometre (RTK).

Operating ratio (percent) is the operating revenue expressed as a percentage of operating costs, sometimes referred as the Revex ratio.

Passenger-km or Revenue passenger-km (RPKs) is obtained by multiplying the number of fare paying passengers on each flight sector by the flight distance. They are a measure of an airline's passenger traffic.

Passenger load factor (percent) is revenue passenger-km (RPKs) expressed as a percentage of available seat-km (ASKs) on a single sector; this is simplified to the number of passengers carried as a percentage of seats available for sale.

Payload capacity total aircraft capacity available for the carriage of passengers, baggage, cargo or mail measured in metric tonnes

Revenue tonne-km obtained by multiplying amount of freight charged for weight in tonnes per km of distance travelled.

Seat factor or passenger load factor on a single sector is obtained by expressing passengers carried as a percentage of seats available for sale; on a network of routes it is obtained by expressing the total passenger-km's (RPKs) as a percentage of the total seat-km's available (ASKs).

Slot at an airport is the right to operate one take-off or landing at that airport within a fixed time period.

Sector/sector distance the air route or flying distance between two airports.

1 CHAPTER ONE: INTRODUCTION

Kane (1996) states that the airline industry provides a transport service for passengers and freight for an agreed price over long distances. It possesses the advantage that it is a safe and time saving means of travel and is most times the only effective link between continents. This industry is characterized by the following challenging factors:

1. Service industry in which no actual goods are exchanged.
2. Highly capital-intensive industry that needs large sums of money to operate.
3. High cash flow since the value of expensive aircraft depreciates over time.
4. Labour intensive with labour contributing a high percentage of operating costs.
5. Thin profit margins of about 1 to 2 percent annually.
6. Seasonality in passenger demand, such that airline revenue fluctuates throughout the year.

1.1 Background

The New Partnership for Africa's Development (NEPAD, 2002) objective is a pledge by African leaders based on a common vision and 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, 2002). The field to be addressed in light of the above objective is the airline industry in Africa

Apart from the crucial characteristics of the airline industry stated above, the African aviation industry 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.

The chairman of the African Airline Association (AFRAA, 2000) states that the 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. After the September the 11th 2001 attack on the World Trade Center in New York, stricter aircraft security standards were enforced putting a strain on airlines especially in Africa. With all of the above financial and management 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, which continually operate at a loss.

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1.2 Problem statement

There are many problems facing the African airline industry including; privatization, stricter aviation regulations, lack of funding, etc. the problems that will be focused on in the study are highlighted from the issues below:

1. It costs the same amount of money to fly from Johannesburg, South Africa to Entebbe Uganda, as it does to fly to from Johannesburg to London Heathrow. Granted the airline industry has many factors that determine the cost of flying a route, depending on passenger demand, route distance, etc. For the purpose of accessibility within a continent with a vision to encourage trade and development within a continent, airfares within the same continent should not be so over-priced.

2. Some of the non-African airlines flying to destinations within the Africa continent have created hubs in Europe to build passenger volumes, increasing passenger-km. This has discouraged air traffic movement within the continent. For example for a long while direct routes to West Africa were minimal, and entailed hubbing either in North Africa or Europe, for connecting flights to African destinations.

From these issues, the following questions need to be addressed, to bridge the gap within countries in the African continent.

1. 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?

2. 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 Purpose for this study

In light of the above issues, the aim of this study will be to develop a model to calculate the cost of running an airline service, along a route in Africa. This model will be developed from existing cost information, in such a way that the operating costs of running this service along any given route can be calculated for the African region, as a way forward to integrate the continent.

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1.4 Scope of study

The main objective of the study is to develop a cost model, while the specific activities include:

1. To review the literature to understand airline route costing and analyse cost structures.
2. To develop a model structure that will calculate the cost of flying a route.
3. To collect and modify relevant data, default values and component equations needed in the model.
4. To assess the model's ability to cost an air transport service.
5. To apply the model to cost different routes within the African region.

1.5 Limitations

From the data available, a route cost model based on passenger volumes will be obtained. Degrees of freedom i.e. the altitude of cruising allowed for specific countries, airport capacities, flight weekly frequencies as specified by authorities, time slots, environmental issues on noise and pollution, and the politics surrounding the airline business, will not be considered.

The airline service will be designed as a traditional passenger airline service -from its origin to destination. It is therefore not a specialized modern airline such as a low cost carrier or freight carrier.

1.6 Methodology

The methodology includes the following components:

1. Develop an understanding of costing an airline service, in terms of structure and relevant determinants.
2. Set up and develop a logical model structure, explaining the input, output and calculation components to cost the route service.
3. Collect and analyse data needed to develop the cost model and where information is lacking, assumptions will be made for parameters in the model.
4. Apply the parameters and relevant equations to calculate operating costs for a route.
5. Analyse the model in its ability to cost an airline service along a route and as a transport service.
6. Apply the model to the Africa situation, with the possibility of creating a network.

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1.7 Organization of the report

This report consists of the following chapters:

1. Introduction

   This chapter gives an overview of what is to be expected in the study, giving the background of the study, the problems to be addressed, specific objectives and the methodology to be followed.

2. Airline Route Costing

   This chapter compiles all the available literature on the cost components and structure to be considered, when looking at operating costs of an airline service. The factors that affect the route operating costs are also discussed. The cost structure to be adopted in the model is finalized.

3. Model Structure

   The structure of the model to be developed is generated and relevant equations compiled in a systematic structure to calculate the operating costs for a given route.

4. Data Collection and Analysis

   Sources of data, component equations and default values relevant in calculating the operating costs of an airline, are compiled. Where data is lacking the assumptions made were justified.

5. Model Analysis

   The model is then analysed in such a way that it can be used to calculate route-operating costs and be used to determine the type of service being served along a route.

6. Model Application

   The results from the model are then used to gauge whether it can be applied to create an economically efficient transport service along the route.

7. Conclusions and Recommendations

   The conclusions drawn from the study are compiled, giving inferences and recommendations compiled in the study.

2 CHAPTER TWO: AIRLINE ROUTE COSTING

2.1 Overview

This chapter uses the literature review to highlight the different airline cost structures, in order to understand the cost breakdown. The components that will be used in the model will be discussed in this chapter. The relevant data to be collected and equations to be used will be formulated.

The rest of the chapter will elaborate on the factors that are crucial in airline management to control operating costs for the purpose of understanding airlines' route and service economics.

2.2 General structure of airline costs

2.2.1 Introduction

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 and whether it will be profitable. The way the costs are broken down and categorized will depend on the purpose for which they are being used.

Kane (1996) outlines the three purposes for cost information in airline planning as:

1. Airlines require an overall breakdown of their total expenditure into different cost categories as a general management and accounting tool. They need to show a general breakdown of costs to show cost trends over time, to measure the cost efficiency of particular functional areas (such as flight operations or passenger services) and ultimately to enable them to measure their operating and non- operating profits or losses.
2. An assessment of costs is essential in evaluating investments either in a new aircraft, route or service.
3. Cost identification is crucial in the development of pricing policies and pricing decisions.

2.2.2 Standard structure

Doganis (1989) states that world wide in the airline industry there tends to be a standard approach in the categorization of costs for general management use.

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Airline accounts are generally divided into operating and non- operating categories, so as to identify and separate out as non- operating items all those costs and revenues not directly associated with the operation of an airline's own air services.

1) Non- operating Items

Doganis (1989), defines the ICAO breakdown for Non -Operating Items as shown below:

1) Gains or losses arising from retirement of property or equipment, both aeronautical and non-aeronautical. These arise from the difference between the depreciated book value of an item and the value that is realized, when an item is sold off.
2) Interest paid on loans, as well as any interest received from bank or other deposits.
3) All profits and losses arising from the airline's affiliated companies, some of which may be directly involved in air transport. This item, in some cases, may be important in the overall financial performance of an airline.
4) Other items which do not fall into the three previous categories, such as losses and gains arising from foreign exchange transactions or from sales of shares or securities.
5) Direct government subsidies or other government payments.

2) Operating Items

The operating items will then be grouped as those sources of income and revenue that are directly associated with running of the airline service. According to airline accounts these items are further subdivided into direct operating and indirect operating costs.

I. Direct Operating Costs

These include all those costs, which are associated with, and dependant on the type of aircraft being operated and which would change if the aircraft type were changed. Stratford (1973) divides the direct operating cost into elements including:

1. Standing Costs, including depreciation of the capital invested in flight equipment as well as the insurance and interest associated with the flight equipment.
2. Flying costs, including crew, fuel and oil, landing fees and direct maintenance and overhaul costs.
3. Other costs which would represent the special costs of significance to the particular exercise in hand.

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Note:

Doganis (1989) specifically states that there are some items however, such as maintenance, administration or costs of cabin staff, which are categorized as direct costs by some airlines and as indirect costs by others. Furthermore, maintenance and overhaul costs cover not only routine maintenance and maintenance checks but also periodic overhauls and repairs. They encompass labour costs and expenses related to all grades of staff involved directly or indirectly in maintenance work. The costs of components and spare parts consumed are also included, as are the costs of workshops, maintenance hangars and offices.

II. Indirect Operating Costs

Doganis (1989), outlines that the indirect operating costs include the following:

1. Station and ground expenses, which are incurred in providing an airline's services at an airport other than the cost of landing fees and other airport charges, e.g. cost of ground handling and aircraft, passenger or freight servicing.
2. Cost of Passenger services whose largest single element is staff cost, including pay, allowances and other expenses directly related to aircraft cabin staff and other passenger service personnel. The second group consists of those costs, which relate directly to passengers like in-flight catering, and finally the premiums paid by the airline for passenger liability insurance and passenger accident insurance.
3. Ticketing, sales, commission and promotion cost; these include all expenditure, pay allowances, etc related to staff engaged in the above-mentioned activities.
4. General administrative costs; these are usually a small element of an airline's total operating costs, since overhead costs can be directly allocated to a particular activity.
5. Doganis (2001) summarizes the items, which are entailed in the operating costs in Table 1.

Table 1: Components of operating costs

Direct Operating costs	Indirect Operating costs
Cabin/ flight crew salaries and expenses	Station or ground costs
Fuel	Handling
Airport charges	Passenger Services
En route charges	Sales/ Reservations
Maintenance	Commission
Depreciation	Advertising/ Promotion
Aircraft Rentals	General Administration
Insurance	Other

Source: Doganis (2001)

2.2.3 Alternative structure

Stratford (1973) shows an alternative structure that can be used to differentiate cost components in terms of airline or aircraft, shown in Figure 1. Specific operating costs are sorted out in such a way that they enable management to minimise cost expenses in a manner that is appropriate for each component.

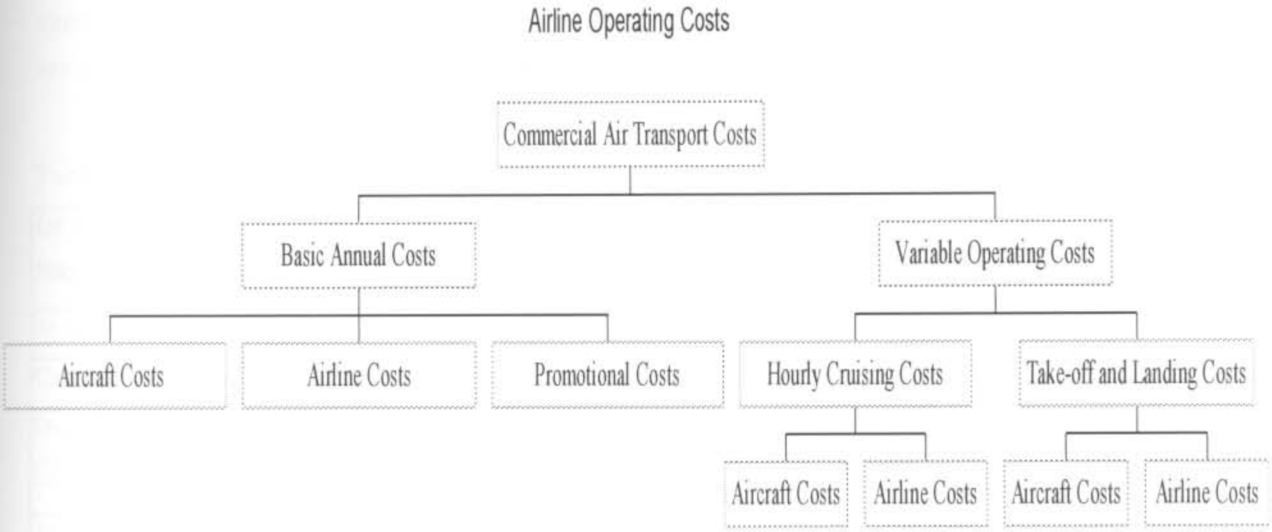

Figure 1: Flow Chart separating costs into airline and aircraft costs (Stratford, 1973)

2.2.4 Towards a structure for the cost model

Table 2 summarises the cost components of Doganis (1989) and Stratford (1973) for the purposes of this study, such that all components are included. The components are divided into standing costs, flying costs and other costs, to differentiate between direct and indirect operating costs. The costs are sub-divided depending on whether the costs are fixed whether the aircraft fly or not and variable, depending on the frequency of flying of aircraft and furthermore as to whether the costs are to be allocated to the aircraft or the airline.

Table 2: Cost structure to be adopted for the model

OPERATIONAL COST BREAKDOWN	Fixed costs		Variable costs	
	Aircraft	Airline	Aircraft	Airline
Standing costs				
Capital	◆			
Depreciation	◆			
Insurance	◆			
Flying costs				
Fuel and oil			◆	
Landing Fees			◆	
Airport and en-route charges			◆	
Direct Maintenance	◆			
Crew costs	◆			
Ground Handling				◆
Other costs				
Passenger Services				◆
Sales/ reservations				◆
Ticketing, sales and promotion		◆		
General administrative costs		◆		

2.3 Components of cost

2.3.1 Utilisation

Utilisation is defined as the average period of time for which the aircraft in question is in use, measured daily, monthly or yearly in block hours. The utilisation of an aircraft is an important factor that needs to be calculated, since most of the costs incurred by the aircraft are spread over how often the aircraft is utilised.

Most aircraft have a maximum annual utilisation for which they have been designed. Stratford (1973), shows that a number of variables influence the value of the total flight utilisation, which may be achieved by an aircraft. Many of the items are inter-related, in that the 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 in Equation 2-1 as:

$$\mathbf{H = nt_f + (n-1)\, t_g} \qquad \text{..............................2-1}$$

$$\textbf{And} \quad \mathbf{t_f = (R/V_b) + t_l} \qquad \text{..............................2-2}$$

Where		
Where	H	the usable hours in the operating day (must be <= 24hrs)
	n	the number of flights per day
	t_f	the mean flight time per route
	t_g	the average ground time at transit and terminal points
	R	the mean distance per route
	V_b	the average block speed of the aircraft
	t_l	the average time lost during take-off, climb, and descent and taxi time.

The number of flights per day for a single aircraft is:

$$\mathbf{n = \frac{H + t_g}{R/\, V_b + t_g + t_l}} \qquad \text{..........................2-3}$$

And annual utilisation (hrs/year)

$$\mathbf{U = D.n.t_f} \qquad \text{..............................2-4}$$

Where D the serviceable operating days in the year

The ATA (1963) method presents the detailed Direct Operating Cost Equation. The costs are calculated as a cost per aircraft statute mile (Cam); however this can be converted such that the block hour costs are inclusive of the lost time at take off and landing.

$$\textbf{Block Hour Cost} = C_{am} * V_b \qquad \text{.....................2-5}$$

$$\textbf{Flight Hour Cost} = C_{am} * V_b * t_b / t_f \qquad \text{.....................2-6}$$

Where C_{am} = Cost per air mile
V_b = Block speed (miles/hr)
t_b = Block time (hrs)
t_f = Flight time (hrs)

Block Speed

For uniformity of computation of block speed, the Equation 2-11 based upon a zero wind component is used:

$$V_b = R / (T_{gm} + T_{cl} + T_d + T_{cr} + T_{am}) \qquad \text{.....................2-7}$$

Where V_b = Block speed in mph
R = Trip distance in statute miles
T_{gm} = Ground manoeuvre time including one minute for takeoff
T_{cl} = Time to climb including acceleration from takeoff speed to cruise speed
T_d = Time to descend including deceleration to normal approach speed
T_{am} = Time for air manoeuvre
T_{cr} = Time at cruise altitude (including traffic allowance)

$$T_{cr} = [(R + K_a) - (R_c + R_d)] / V_{cr} \qquad \text{.....................2-8}$$

R_c = Distance to climb (statute miles) including distance to accelerate from takeoff speed to climb speed.

R_d = Distance to descend (statute miles) including distance to decelerate to normal approach speed.

V_{cr} = Average true airspeed in cruise (mph)

K_a = Airway distance increment due to extra distance that may be flown during the flight time. It's usually calculated as (7 + .015D) up to $D <=$ 1400 statute miles, and $K_a = 0{,}02D$ for $D > 1400$ statute miles.

2.3.2 Capital costs

This being a highly capital-intensive industry means, a big potion of the operating costs are spent on the costs of acquiring the aircraft. The common costs incurred include depreciation, insurance and interest

1) Depreciation

The depreciation period is defined as the period during which an airline will be charged for the expense for the flight equipment losing its value over time. Kane (1996) defines depreciation, as the expense for depreciation of airframes, aircraft engines, airframe and engine parts, and other flight equipment for the time period over which the aircraft is in use.

Doganis (1989) states that airlines tend to use straight-line depreciation over a given number of years with a residual value between 0 and 15 %. The annual depreciation charge or cost of a particular aircraft in the airline's fleet depends on the depreciation period adopted and the residual value assumed.

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.

Depreciation/hr can be calculated using Equation 2-9 from Stratford (1973), which uses the linear depreciation function, shown below:

$$C_{sd} = \frac{(C_{air} + C_{eng} + C_{equ})*(1-r_v)}{L*U} \qquad \text{..................2-9}$$

Where C_{sd} is the cost per hour of the depreciation of the flight equipment

C_{air} is the cost of one furnished airframe with spares

C_{eng} is the cost of the engines installed in one airframe, and the spare engines together with the engine spares holding per airframe.

C_{equ} is the equipment (including radio and radar) installed together with the spares holding of equipment per airframe.

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

U is the average utilisation per aircraft in revenue block hours/year.

The Air Transport Association (ATA, 1963) states that the depreciation of the capital value of an aircraft is dependent to a large degree on the individual airline and the world economic and competitive conditions.

For the purposes of this formula, the depreciation periods in years (L) and the residual value for the aircraft and its components according to the ATA, are given in Table 3.

Table 3: Depreciation and residual values for different aircraft types

Aircraft Types	Depreciation Period (yrs)	Residual Value (%)
Subsonic Turbine Engine Aircraft	12	0
Supersonic Aircraft	15	0

Source: ATA (1963)

Note to Table 3: Financial accounting practice normally recognizes a residual value, however the amount is usually nominal. These values are applicable to complete aircraft, including the engines and all spares (ATA method).

Under the ATA (1963) method, the equation used to calculate depreciation in costs in US$ per air mile (Cam) of the total aircraft including spares is given in Equation 2-10

$$\mathbf{C_{am} = (1.1C_{total} + 0.3\,Ne\,C_{eng}/\ (L^{*}\,U^{*}\,V_b)} \qquad \text{....................2-10}$$

Where: C_{total} = Total aircraft cost including engines (US$)

C_{eng}= Cost of one engine (US$)

N_e = Number of engines

L = Depreciation period (years)

U = Annual utilisation - block hours/year

V_b= Average block speed of the aircraft (miles/h)

According to Doganis (2001), the economic life of an aircraft was formerly dependent on the strength and technical life of their various components and was unlikely to be affected by any new leaps forward in aircraft technology, that might make them obsolescent. But with time, in response to these two factors and to their worsening financial performance, airlines throughout the world changed. Doganis states that at the moment, airlines have tended to lengthen the depreciation period of their large wide-bodied jets to 14-16 years with a residual value of around 10 percent. For smaller short-haul aircraft the depreciation period is shorter, generally 8-10 years.

2) Interest

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.

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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 which Development banks, or the World Bank lends money. This value would be more representative than the rates at which financial lending institutions like commercial banks lend money to an individual.

3) 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 of the flight equipment shows 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 the airline, the number of aircraft it has insured, and the geographical areas in which the aircraft operates. The annual premium is converted into an hourly insurance cost by dividing it by the projected annual aircraft utilisation that is defined as the total number of block hours that each aircraft is expected to fly during the year.

Stratford (1973) shows that it is standard practice to make an allowance for insurance as part of standing costs of operation, since these costs are high. Thus 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:

$$\mathbf{C_{ins} = (x * C_{total}) / U} \qquad \text{....................} \ \mathbf{2\text{-}11}$$

Where: C_{total} =Total cost of aircraft, engine and equipment.
X = Annual insurance premium rate

The insured value rate is assumed to cover 100% of the initial price of the complete aircraft

$$C_{am} = (\text{Rate/US\$ Value}) \ (\text{Aircraft Cost}) / \ (\text{Utilisation})$$

$$\mathbf{C_{am} = IRa * C_{total} \ / \ (U * V_b)} \qquad \text{....................} \ \mathbf{2\text{-}12}$$

Where: IRa = Rate per US$ value
C_{total} = Total aircraft cost including engines (US$)
U = Annual utilisation - Block hours/year
V_b = Block speed (air miles/h)

2.3.3 Fuel and oil

Doganis (1989) states fuel as another major element in the cost of flight operations. The consumption of fuel varies considerably from route to route in relation to the sector length, the aircraft weight, wind conditions, cruise altitude and so on. Thus the hourly fuel cost tends to be even more of an approximation on a route-by-route basis. Fuel costs include all relevant taxes levied by the specific government.

The ATA (1963) method refers to the amount of fuel needed by the aircraft during the block time, as the block fuel whereby block fuel is comprised of the following components, all of which use varying amounts of fuel, and the summation of which will be the block fuel:

$$F_b = F_{gm} + F_{am} + F_{cl} + F_{cr} + F_d \qquad \text{....................2-13}$$

Where F_b = Block fuel in US gallons

F_{gm} = Ground manoeuvre fuel based on fuel required from engine on to take –off at runway assumed to be 14 minutes + 1 minute at takeoff thrust or power.

F_{cl} = Fuel to climb to cruise altitude including that required for acceleration to climb speed.

F_{cr} = Fuel consumed at cruise altitude (including fuel consumed in 20 statute mile traffic allowance and allowance for airway distance increment Ka).

F_{am} = Six minutes allowed for air manouveur from cruise altitude to altitude when aircraft begins descent.

F_d = Fuel required to descend including deceleration to normal approach speed.

Reserve Fuel

The reserve fuel is the amount of extra fuel besides block fuel in the tank that should be used for emergency procedures. The ATA (1963) method also elaborates on reserve fuel depending on the distance and type of aircraft. The emergency procedures are in excess of minimum Federal Aviation Regulations and are representative of airline operational practices. This excess is not related to safety requirements. The maneuvers specified in this study will only look at those for international flights within Africa and not domestic flights within countries.

Reserve fuel is needed to perform the following maneuvers, for international flights:

(1) Fly for 99% maximum range of aircraft, for 10% of trip airtime at normal cruise altitude, plus the fuel flow for end of cruise taking into account landing weight at specific speed.

(2) Exercise a missed approach and climb out at the destination airport, fly to an alternate airport 174 statute miles distant.

(3) Hold for 30 minutes at alternate airport at 15,000 feet altitude.

(4) Descend and land at alternate airport.

Fuel consumption

Block fuel calculated in Equation 2-14, is the amount of fuel used up at the block time, as a product of fuel consumption given in terms of volume (US gal/hr) in Equation 2-15. The weight of fuel being consumed at climbing, descending and cruising is determined by the following factors; engine thrust, Specific fuel consumption (SFC), and the number of engines, using the formula in Equation 2-16. Airliners.net (2004) in discussions quotes that the fuel consumed at cruise is dependent on cruise thrust and cruise SFC, while the fuel at climbing, also depends on climbing thrust and the engine SFC. The volume of fuel consumed can then be obtained by dividing the weight of fuel consumed by the fuel density, in Equation 2-15.

$$\mathbf{F_b = F_v \times t_b} \qquad \text{..................2-14}$$

$$\mathbf{F_v = F_w / F_d} \qquad \text{.................. 2-15}$$

$$\mathbf{F_w = SFC \times T \times N_e} \qquad \text{.................. 2-16}$$

Where F_b= Block Fuel (US gal)

F_v= hourly consumption of fuel (volume) (US gal/hr)

F_w = Hourly Consumption of fuel (weight) (Ib/hr)

F_d =Fuel Density (Ib/US gal)

SFC = Specific fuel Consumption (Ib/Ibfhr)

T = Thrust at (Ibf)

N_e = Number of Engines

Oil consumption

Oil consumption is negligible, so rather than calculate it on a route basis an hourly figure for oil consumption for an engine type, for a given number of engines for the aircraft flying a sector, for the given block time is used

A volume ratio of fuel to oil is specified for the proper operation of an aircraft engine, and will be applied in the model to calculate the volume of oil consumed per block hour. The two data sources that give a fuel: oil ratio is given in Table 4, and the default ratio that will be used in the model will be specified

Table 4: Fuel to oil ratio

Engine	Fuel: oil ratio	% Lubricant mix	Data Source

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Simjet miniature	25:1	4	Rolls Royce (2003)
Aj/TJT-3000	20:1	5	Turbine design (2002)

Turbo jet technologies ratio will be used because it is specified for an actual turbo jet engine being used in the market today, while the Simjet is an engine used for miniature jets. This implies that for whatever volume of fuel is consumed per block hour, a 20: 1 ratio will be used to calculate the volume of oil, in US gallons that will be changed to quart by multiplying it by 4.

The ATA (1963) formula for calculating cost of fuel and oil per air mile is stated below, assuming the factor 1.02 in equation 2-17 caters for the 2% factor of reserve fuel.

$$\mathbf{C_{am} = 1{,}02 * (F_b * C_{ft} + N_e * 0{,}135 * C_{ct} * t_b) / D \quad \ldots\ldots\ldots\ldots\ldots\ldots..2\text{-}17}$$

Where: F_b = Block fuel Volume (US gal)
C_{ft} = Cost of Fuel per US gallon
C_{ct} = Cost of oil for turbine engines consumed per flight hour (US\$/US gal)
Ne = Number of engines installed
D = Sector Distance

This formula will be altered and converted to cost per block hour, in order to be applied.

$$\mathbf{C_{ah} = 1{,}02 (V_f * C_{ft} + 0, 135 * C_{ot} * V_o) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots2\text{-}18}$$

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

Fuel and oil prices

Emery (2002) states that fuel, especially in the African aviation industry, is still an important operating cost for airlines and currently makes up about 10 percent of direct operating costs. Furthermore, he states that the price of jet fuel fluctuates according to world oil prices and currently the price is about 80 US cents per US gallon.

The difference in percentage make up of fuel prices in the world to day could be attributed to many changes in supply, demand, market prices and the availability on the world market.

Emery (2002) states that for aviation in Africa, fluctuations in the home currency of each country, and government taxes, can have a significant impact on profit since fuel is paid in US dollars.

The particular concern in Africa is airport location, IATA has set up a fuel trade panel whose duties are to ensure reliable fuel supply at all international airports and minimise taxes and user charges on aviation fuel. Table 5 shows what elements, are comprised in the cost of fuel:

Table 5: Aviation fuel make-up cost

Cost	US cents/ US gallon	Notes
Fuel	80	Varies by distance from refinery or sea
Government Taxes	5	Varies
Fee for storage facility throughout	2	Much less at large storage facilities
Hydrant Use fee	0,5	
Into-plane fuel loading (refueller charges)	2	
Total in-plane cost	**89,5**	

Source: Emery 2002

Turbo-jet Technologies (2002), gives the cost of oil used in turbo jet engines; the price of oil is given in units of US$/quart as 0,233. The price to be used per US$ per US gallon will be 0,932 for the model.

2.3.4 Airport and en-route charges

Stratford (1973), states that the landing fee is an item included as a direct operating expense and is of significance in actual and comparative aircraft cost estimates. The 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.

Doganis (1989) adds that airport charges normally include two elements; a landing fee and a passenger charge; the former relating to the weight of the aircraft and the latter relating to the number of passengers disembarking from an aircraft. Most airports presently collect a fee directly from the passengers, termed the airport tax on departures and is included in the fare paid. The landing fee is usually paid directly to the airport by the airline as a separate charge. Kane (1996) states that the airport landing fees and rents worldwide have been rising at four times the rate of inflation in recent years, due to the fact that the airline industry has become a popular means of travel over the years.

Doganis (1989), states that en-route navigation charges serve to cover the cost of traffic control and navigational and other aids. They are imposed by civil aviation authorities and are related to the weight of the aircraft and the distance flown over a country's airspace. Thus these levies are in essence a direct cost since they vary with the type of aircraft flown and distance travelled.

2.3.5 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. Doganis (1989), states that they can be calculated either on a route -by-route basis or are expressed as an hourly cost per aircraft type.

The latter case will be adopted for this study and calculated by multiplying the hourly flight crew costs of the aircraft type being operated on the route by the block time for the route

In 1963, the ATA derived costs from a review of several representative crew contracts. Based on this review, yearly rates of pay were arrived at which were used with welfare, training, travel expense, and crew utilisation factors to produce the crew cost equations shown in Table 6 (ATA, 1963).

Table 6: Flight crew cost equations (ATA, 1963) (US$/air-mile)

Engine Type	**Domestic Subsonic Aircraft**		**International Planes**
	Two-Man Crew	**Three-Man Crew**	**Three-man crew**
Turbo Jet	[0,00005 ToGWmax + 100] / V_b	[0,00005 (ToGWmax + 135] / V_b	[0,00005 ToGWmax + 200] / V_b
Turbo Prop	[0,00005ToGWmax+ 63] / V_b	[0,00005 (ToGWmax+ 98] / V_b	**For each additional member**
			+ [35] / V_b

Source: ATA 1963

Where C_{am}= Costs per air statute mile in US$
$ToGW_{max}$= Maximum certificated take-off Gross Weight (lb)
V_b= Block Speed (mph)

The equations from ATA are based on speed in statute miles per hour and the ToGWmax in pounds, whereas the units for the model will be metric units. The crew cost equation values of speed will have to be changed to km per hour and the weight to be converted to kilograms. The crew cost equation that will be used in the model is shown in Table 7:

Table 7: Crew costs per hour (US$/flight hour)

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

2.3.6 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.

There are two well-established procedures being used for the maintenance of aircraft, namely periodic and progressive. The use of either of these procedures is dependent on the policy set forth by the individual airlines and generally the costs will be approximately the same. All equations have been quoted as given by ATA that had no derivations of them.

The ATA remarked that the close study of operating statistics shows that the average cost of maintenance may be fairly represented as a function of weight, thrust, and flight cycles. Table 8 summarizes the equations to calculate maintenance and Table 9 compiles the items used to calculate maintenance and their respective equations:

Table 8: Maintenance costs equations (US$/air mile)

Maintenance costs	Cost per air mile
Labour - Aircraft	$C_{am} = (KF_{Ha} * t_f + KF_{Ca}) * R_L /(Vb * T_b)$
Labour - Engine	$C_{am} = (KF_{He} * t_f + KF_{Ce}) * R_L / (V_b * T_b)$
Material - Aircraft	$C_{am} = (CF_{Ha} * t_f + CF_{Ca}) / (Vb * T_b)$
Material - Engine	$C_{am} = (CF_{He} * t_f + CF_{Ce}) / (V_b * T_b)$

Source: ATA (1963)

Where: R_L = Labour rate (US$/block hr)
W_a = Basic empty weight of the aircraft less engines (lb)
V_b = Aircraft speed (mph)
T_b= Block time (hr)
t_f= Flight time (hr)
$C_{air=}$ Cost of complete aircraft less engines (US$)
T = Maximum certificated takeoff thrust (lbf)
N_e = Number of engines

Table 9: Equation components

Item	Equation	Units
CF_{Ha}	$3,08\ C_{air}/106$	Material cost (US$/flight hour)
CF_{Ca}	$6,24\ C_{air}/106$	Material Cost (US$/flight cycle)
KF_{Ce}	$(0,3 + 0,03\ T/103)$	Labour man-hours per flight cycle
KF_{Ha}	$(0,6 + 0,027\ T/ 103)$	Labour man-hours per flight hour
KF_{Ce}	$0,05 * Wa / 1000 + 6,630 / (Wa/1000 + 120)$	Labour man-hours per flight cycle (jets and turboprop)
KF_{He}	$(0,65 + 0,03\ T/103)$	Labour man-hours per flight hour (turboprop)

Source: ATA 1963

Notes to Table 9: Labour - Aircraft (Excluding engines only). Material - Aircraft (Excluding engines only). Calculations of which are shown in Table 10.Labour and material- Engine (includes bare engine, engine fuel control, thrust reverse, exhaust nozzle systems, and augmentor systems, gear box but excludes the propeller on turboprop engines). The labour rate, in case used will be acquired appropriately for Africa's case.

Table 10: Material costs for aircraft

Types	Material cost per flight cycle (CF_{Ce})	Material cost per flight hour (CF_{He})
Subsonic aircraft	$0,02\ N_e\ C_{eng}$	0,25 Ne Ce

Source: ATA 1963

Where; N_e = Number of engines

C_{eng}= Cost of one engine

According to all the maintenance equations that have been developed, there is a need for factors like labour rate, which varies significantly between African countries depending on the economic situation. In the literature review, maintenance of the aircraft is related to depreciation, which relates to the capital cost of the aircraft

2.3.7 Percentage allocation of costs

Table 11 gives the summaries of the percentage structures found in the stated references. Kane (1996) gives the Department of Transport (US) structure while the ICAO structure is given by Doganis (1989).

Kane (1996), states that labour costs are common to nearly all of those categories. When looked at as a whole, labour accounts for 35% of the airlines' operating expenses and 75% of its controllable

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costs. Fuel is another major cost item (about 15% of total expenses). So are travel agents' commissions (about 10%). Commissions have been one of the fastest rising airline costs since deregulation, when they accounted for less than 5% of total costs. Another rapidly rising cost has been airport landing fees and rents, which have been rising at four times the rate of inflation in recent years. For world's airlines, user charges, which include airport charges and en-route facility charges, account for nearly 5 % of their total costs.

The difference in the percentage of allocation costs, between 1989 and 1996 is due to different operating structures between the Department of Transport of the US government and the international airline body ICAO. This would explain the different allocation of sub-components of operating costs, in different operating environments; ICAO takes into account all international member airlines and arrived at a general average structure.

Table 11: Percentage distribution of operating Costs

Operating costs	**Scheduled airlines of ICAO, 1982 After Doganis (1989)**	**Dept of Transportation US After Kane (1996)**
Direct Operating Costs		
Flight operations	41,7	28
Flight crew salaries / expenses	(7,3)	
Fuel and oil	(27,2)	
Air port and en-route fees	(4,7)	
Insurance and aircraft rentals	(2,5)	
Maintenance and Overhaul	9,8	11
Depreciation and Amortisation	6,8	6
Total DOC	**58,4**	**45**
Indirect Operating Costs		
Station to ground	10,8	25
Passenger services	9,1	
Ticketing, sales and promotion	15,5	18
General and administration	6,1	12
Total IOC	**41,6**	**55**
Total Operating costs	**100,0**	**100**

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Sales, ticketing and promotion charges

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. The costs of advertising, marketing promotion, commission or fees paid to agencies for ticket sales also fall under this category.

In Table 11, 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%) can be used to calculate the item.

General administration

In Table 11, 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.

Maintenance

Table 11 shows the relationship between the costs of components from Department of Transport (US) (Kane, 1996) and ICAO (Doganis, 1989). The more detailed ICAO data from international member airlines reflects that insurance and maintenance amount to 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.

Stratford (1973) also shows the parameters and their economic units to be used in quantifying the costs in Table 12. The unit system that is quoted in the references is quite old so it will be used when quoting values and figures from references.

For the purposes of this study, the metric system will be adopted.

Table 12: Economic units to quantify costs

COST ITEM	UNITS
Cruise performance data	
First cost of complete aircraft Engine type, number and first cost	$
Spares cost per aircraft	
Airframe	$
Engine	$
Radio/ Equipment	$
Maximum all-up weight	Ib
Basic operating weight with/ without special equipment	Ib
Annual utilisation	Flight Hours/aircraft hours/block hours
Depreciation Period	Years
Residual Value	%
Insurance rate of flight equipment	% Per annum
Interest on Capital	% Per annum
Basis of engineering costs	
A) Airframe engineering costs	$ Per block hour
B) Engine maintenance and overhaul costs	Man hours per annum
c) Equipment and component overhaul, mean attained period between engine overhauls	Hours
Maintenance labour rate	$/ Direct man-hour
Crew costs (No. in crew)	$/ Annum
Crew Utilisation	Hours/annum
Fuel costs	$ Per flying hour
Landing fees	$ Per landing

Source: Stratford (1973)

Notes to Table 12: Kilograms will be used instead of pounds for weight. Costs in US$ will be given in block hours not in terms of labour hours

2.4 Aspects that determine route costing

2.4.1 Management control of costs

Doganis (1989) states that the variable operating costs, which may represent about 50 percent of total operating costs, which are broadly determined by the level of supply, that is the volume of output are decided upon by the management. This statement implies that management decisions in some of these variable operating cost components has an impact on the costs. Some of the components over which management has control, are outlined below.

2.4.2 Prevailing wage levels

Doganis (1989) states that labour costs have become a point of focus, because they have become the largest single cost element varying in extent from 15 - 40 percent. In addition, it is a major factor differentiating one airline's unit costs from another.

Hanlon (1999) states that the importance of labour costs in the overall cost structure of an airline is dependent on the interplay of two groups of factors, those relating to the relative costs of labour and those that determine the productivity of the labour. In other words labour costs depend on the unit cost of labour as an input and the amount of that labour that is required to produce a unit of output.

2.4.3 Fuel prices

The price of aviation fuel at any airport depends partly on the companies supplying the fuel and partly on the government concerned. Prices for fuel worldwide differ in distribution and handling costs, foreign exchange rates, etc. (Doganis, 1989)

Table 13 is an extract from Doganis (1989) that shows the fuel prices for different continents extracted from ICAO (1984b). He also states that the price of fuel is crucial for airlines since on any particular route it may represent as much as 40 percent of operating costs, though overall it accounts for one of the biggest potion of the total operating costs of many airlines.

Table 13: Fuel prices on international scheduled services 1982

Route Group	**Average fuel or oil price paid. (US cents per US gallon)**	**Index (North America = 100)**
Africa	163,9	184
South America	127,2	142
Asia/Pacific	118,8	133
Europe	117,0	131
North America	89,3	100

Source: Doganis (1989)

For the Africa situation, in Table 13, the price of fuel is 163, 9 while in Table 5 the price per US gallon is 89,5, this change is attributed to the year in which the data was collected. Table 13 quotes 1982 prices while the price in Table 5 is a 2002 quotation, which would be more representative.

2.4.4 Route traffic density

The main determinant of unit cost is route traffic density. In this context, density can be measured as the ratio of traffic to network size; i.e. passenger miles divide by unduplicated route mileage, or passenger miles divided by the number of cities served.

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 mile and/ or to operate at higher service frequencies, consequently at higher seat load factors, which lead to lower cost per passenger mile.

2.4.5 Average sector length

Kane (1996) defines the sector length as the overall physical length of the route in miles. The greater the number of miles produced on a certain route by a given aircraft will tend to decrease the per-mile cost of operating the aircraft. The fixed cost, for a given flight will remain fixed regardless of the total miles flown. This fixed cost, spread over more miles, will result in lower fixed cost per mile.

Hanlon (1999) also states that higher block speeds and better fuel economies are achieved on longer routes. The hyperbolic relationship between unit cost and sector length, shown in Figure 2, is a fundamental characteristic of airline economics, and the airlines with the lowest cost per seat mile are those operating large aircraft over long sectors.

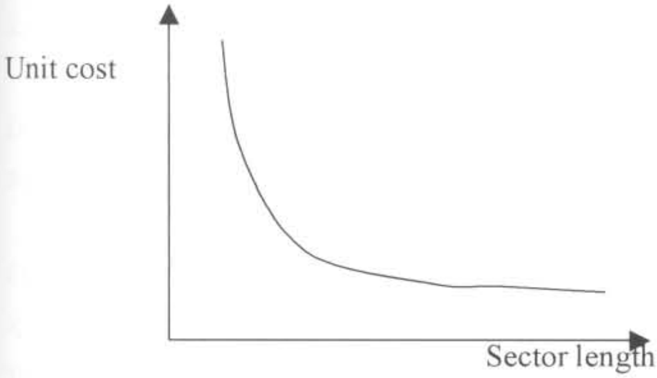

Figure 2: Hyperbolic relationship between unit cost and sector length

Doganis (2001) finds that for each aircraft type, the longer the sector length, which can be flown the lower the direct operating cost per available seat-mile, a relationship similar to the one shown Figure 2.

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2.4.6 Average length of haul

The average length of haul is the average distance flown by passengers over an air carrier route. A route may be a thousand miles long, but if the average passenger disembarks after two hundred miles, his vacated seat may well remain empty for the remainder of the flight. Kane (1996) states that this can of course be prevented by non-stop flights, but these are not always possible especially if the air carriers must also serve intermediate points along the route.

Doganis (2001), states that many costs associated with sales, ticketing and the handling of passengers are related to the number of passengers rather than to the distance that each passenger travels with the airline on a particular journey. In other words, a passenger who buys a single ticket and travels 3 000km on an airline network will cost less to an airline than three separate passengers each traveling 1 000km. In the latter case, each of the three will impose individual ticketing and handling costs and the airline may have to pay a separate airport charge for each.

2.4.7 Load factors

Kane (1996) defines load factor as the percentage that revenue passenger-miles are of the seat-miles provided. A break-even load factor is computed for an aircraft type over any given route. It is equal to the percentage of the aircraft, which must be filled by passengers or other traffic in order for the airline to cover its direct operating costs for the flight. This point must obviously be reached before a profit can be achieved.

2.4.8 Aircraft type and characteristics

Doganis (1989) shows the influence of different aircraft characteristics that affect costs. Aircraft size, speed and range together determine a productivity curve of an aircraft and hence its unit cost.

From an economic point of view, the most important factors are the size of the aircraft; it's cruising speed and the range or distance, which that aircraft can fly with a full payload. The significance of size, speed and range is reinforced, in that taken together they determine the hourly productivity of an aircraft, which in turn also affects unit costs. As a general rule, the larger the aircraft the lower will be it's direct operating costs per unit of output (i.e. per tonne - km available or per seat- km).

Aircraft speed, through its effect on the hourly productivity of an aircraft, affects unit cost. Hourly productivity of an aircraft is the product of the payload and the speed, the greater the aircraft cruising speed the greater will be its output per hour.

Aircraft are designed to cater for particular traffic densities and sector lengths. Therefore, each aircraft type has different take-off and range characteristics and these in turn influence unit costs (See Chapter 5).

2.4.9 Route competition

Kane (1996) states that competition on the route due to other airlines or transport modes produces better airline service in the public interest. But in situations where there is not enough air traffic to support the airlines serving a route, it creates un-profitability because competition among these airlines leads to addition of expensive perks to attract the market. Competition for given routes is commonly caused by:

1. Creation of new air carriers
2. New routes of existing airlines into areas already being served by other airlines
3. Mergers of airline companies or route consolidations that monoplise market on routes and set minimum fares.

2.4.10 Frequency of services

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. Antolini (2002) states that on long haul routes high frequencies also enable airlines to reduce the length and cost of crew stopovers.

2.4.11 Demand for air travel

The three fundamental factors affecting passenger demand are incomes, fares and service levels. Broad estimates of aggregate elasticities imply that demand is highly elastic with respect to economic growth and fares and relatively inelastic with respect to service levels.
The components of air travel demand are co-related as shown in Figure 3:

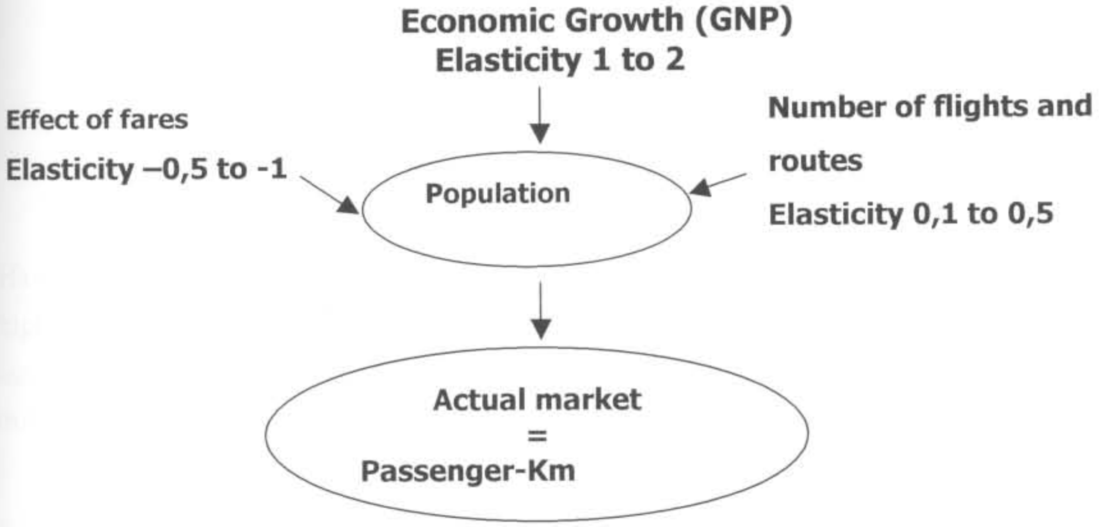

Figure 3: Factors affecting demand for air travel (Source: Hanlon, 1999)

Hanlon (1999) shows that the high-income elasticity can be seen in the short-term series relationship between economic activity and air travel demand. Although air travel tends to grow faster than GDP, it still follows very closely the cyclical pattern in GDP.

2.4.12 Marketing effect

Marketing expenditure serves two functions. One is to increase the airline's share of passenger demand and the other is to make that demand less price elastic. Figure 4 shows the original demand curve (D_1) before anything is spent on marketing. On this schedule, if the fare charged by the airline is P_1, the number of passengers carried by the airline is Q_1. Following a marketing campaign, the demand curve shifts to the right and acquires a steeper slope (D_2). The rightward shift allows an increased number of passengers Q_3 to be attracted to the service at original price or the steeper slope enables the airline to raise the fare to P_2 and still have a substantial increase in passengers to Q_2.

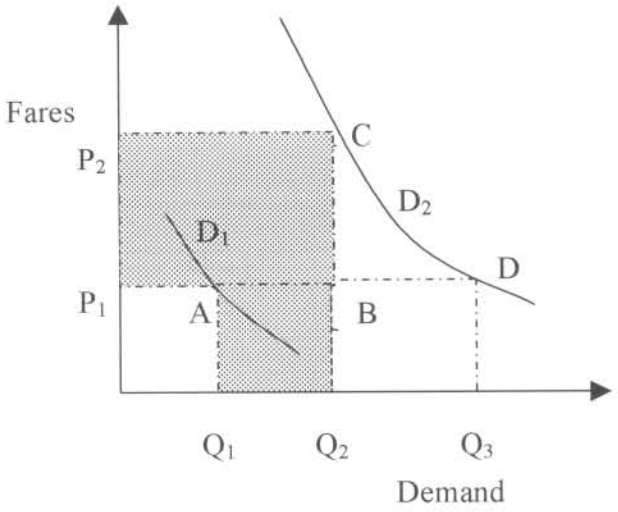

Figure 4: Demand curve for passenger demand (Source: Hanlon, 1999)

Hanlon (1999), concludes that the airline benefits both from an increase in passengers and from a higher fare per passenger; its total gain in revenue is either $(P_2-P_1)*Q_2 + (Q_2-Q_1)*P_1$ if the fares are increased or $P_1*(Q_3-Q_1)$ if the fares are kept the same. So long as this additional revenue is greater than the costs associated with the marketing campaign, the airline increases its profit.

2.5 Summary

From the literature it is evident that the structure shown in Figure 5, depicting the cost components, is the most logical method of developing the model. The operating cost component equations that are used in the model are classified as standing, flying and other costs.

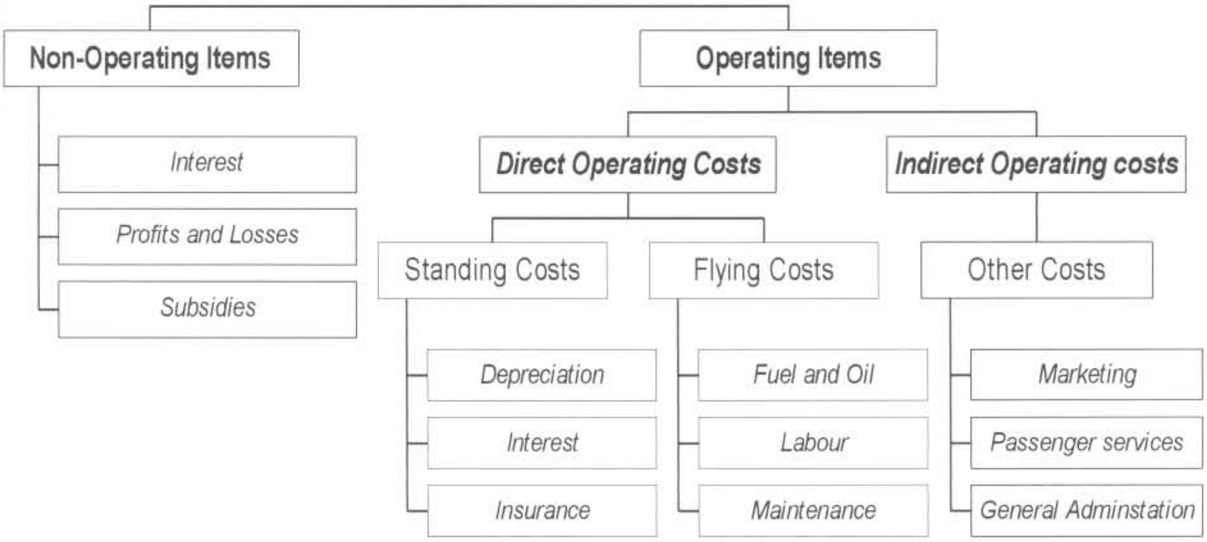

Figure 5: Airline and aircraft cost components

The operating cost component equations derived from the literature, 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 14.

Table 14: Equations used for cost model components

COMPONENTS	EQUATIONS	Parameters
Standing costs (per hour utilised)		C_{total} = total cost of aircraft +engine
Hourly Depreciation	C_{total} $(1-r_v)/L$ *U	r_v= residual value (%)
Hourly Insurance	X * C_{total}/U	U= annual utilisation (hrs)
Hourly Interest	$i*C_{total}/U$ $[1-((1-r_v)(L-1))/2L]$	I =annual interest rate (%)
Flying costs (per hour utilised)		L = life (years)
Fuel and oil (cruising & air manoeuvre)	$C_{ah} = 1.02\ (V_f * C_{ft} + 0,135 * C_{ot} * V_o)$	X =annual insurance rate
Direct Maintenance	9,8 / 2,5 ratio of insurance costs	C_{ft} = cost of fuel (US$/US gal)
Crew costs (3-man crew)	[0,000225ToGWmax + 200]	C_{ot} = cost of oil (US$/quart)
Additional members	+[35]	V_f =Fuel volume consumed at cruising/ climbing (US gal/hr)
Other costs		V_o = Oil Volume consumed at climbing/cruising (quart/hr)
Landing Fees per aircraft	Charges per weight * ToGWmax	ToGWmax = max Take off weight (kg))
Parking Fees per aircraft	Charges per weight* ToGWmax	Tb = block time (hrs)
Passenger Handling per passenger	Charges per Passenger * No of passengers	Vb = block speed (km/h)
Ticketing, sales and commission	15,5% of operating costs	
General administrative costs	6, 1% of operating costs	

The aspects of operating costs that are key to lowering the variable operating costs include minimum and maximum frequency of flights, average sector length, block time, and the route traffic density. These will have to be analysed specifically in the model so as to design for an optimum service along a route.

3 CHAPTER THREE: MODEL STRUCTURE

3.1 Introduction

The route cost model was developed as a Microsoft Excel spreadsheet to calculate the cost of an airline service for each given route, for a specified number of passengers, with a minimum service frequency and for a range of different aircraft modes. The structure of the model is described in this chapter in terms of the input component, the calculation component and the output component.

3.1.1 Assumptions

The following assumptions were made in developing the model:

1. The data that has been collected has been found valid and referenced accordingly.
2. Calculations for the direct operating costs, which include standing and flying costs, are calculated in the rate of hours utilized annually, while other costs like passenger fees are calculated as per unit description.
3. A Flight for this cost model is defined as a return journey, made by any given aircraft on a route, otherwise all calculations are done using sector distance using one leg of the journey.
4. Passenger demand is given as the maximum volume of passengers along the route irrespective of the direction of travel.

3.1.2 Flow chart

Figure 6 shows the flow chart, which comprises of the model that was developed. It gives the systematic layout of the calculations to be done and what information is input to give the output necessary. The model is composed of the following components:

1. The input module containing the characteristics of the route to be used, like distance, passenger numbers (section 3.2) and a data base for default values for each aircraft type like the cruising speed, (Chapter 4 and compiled in Appendix D).
2. The calculation module (section 3.3)
3. The output module (section 3.4)

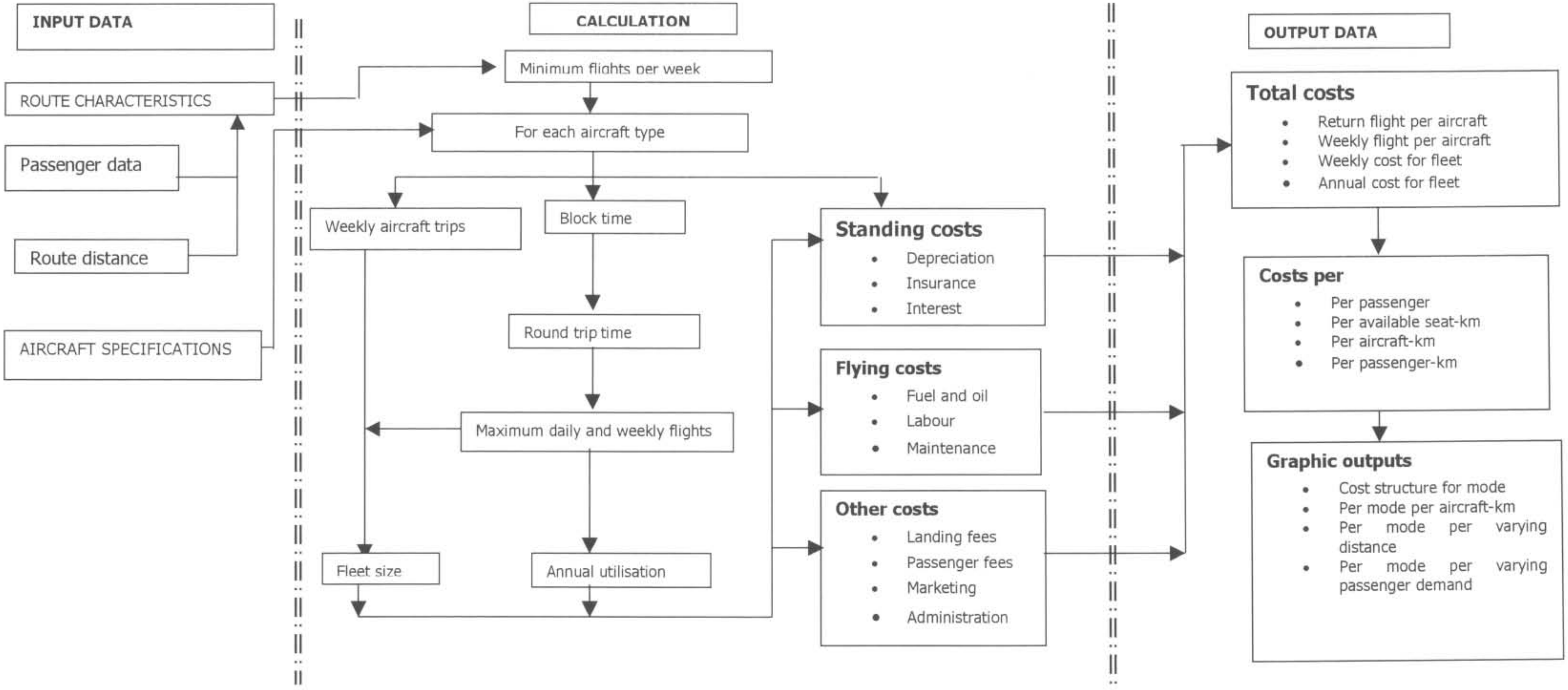

Figure 6: Model flow chart

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3.2 Input module

All the data that serves as input to the model is included in the *Input Sheet*, while the aircraft default values and technical specifications are included in the *aircraft data*. The aircraft data, which includes aircraft technical characteristics like operating speed, default values, and data collected for each aircraft needed to calculate cost components is shown in Appendix D.

The user of the model can input the basic descriptors of the route, for which the cost is to be calculated. The sheet is set up in such a way that the automatic link will always have values and will use these default values, unless the model user decides to use alternative values in the "manual" cell.

3.2.1 Route description

The user of the model needs to specify the origin and destination countries, for the airline service that is being costed. Once the countries have been specified, the IATA Airport codes for the major international airports are linked automatically from the *demography* work sheet. These codes are important because, they are used to identify each airport.

Sector distance

The model user, will then be given the option of either using the automatic distance between the two specific airports, obtained by linking the *distance matrix* in a separate worksheet, or the user can input the actual distance manually.

The model will be set up in such a way, that the automatic link will always have values and will use these default values, unless values in the manual section are provided. When a value is filled in the manual section, it will be the input value used.

Passenger demand

The model assumes that the passenger volumes are equal in both directions. This demand is given in units of passengers/week. The weekly number of passengers can either be derived from the *trip distribution matrix* (See Appendix C) or input manually by the user. The time period used is a week because in the airline industry, the standard unit of time over which frequency is described is usually a week.

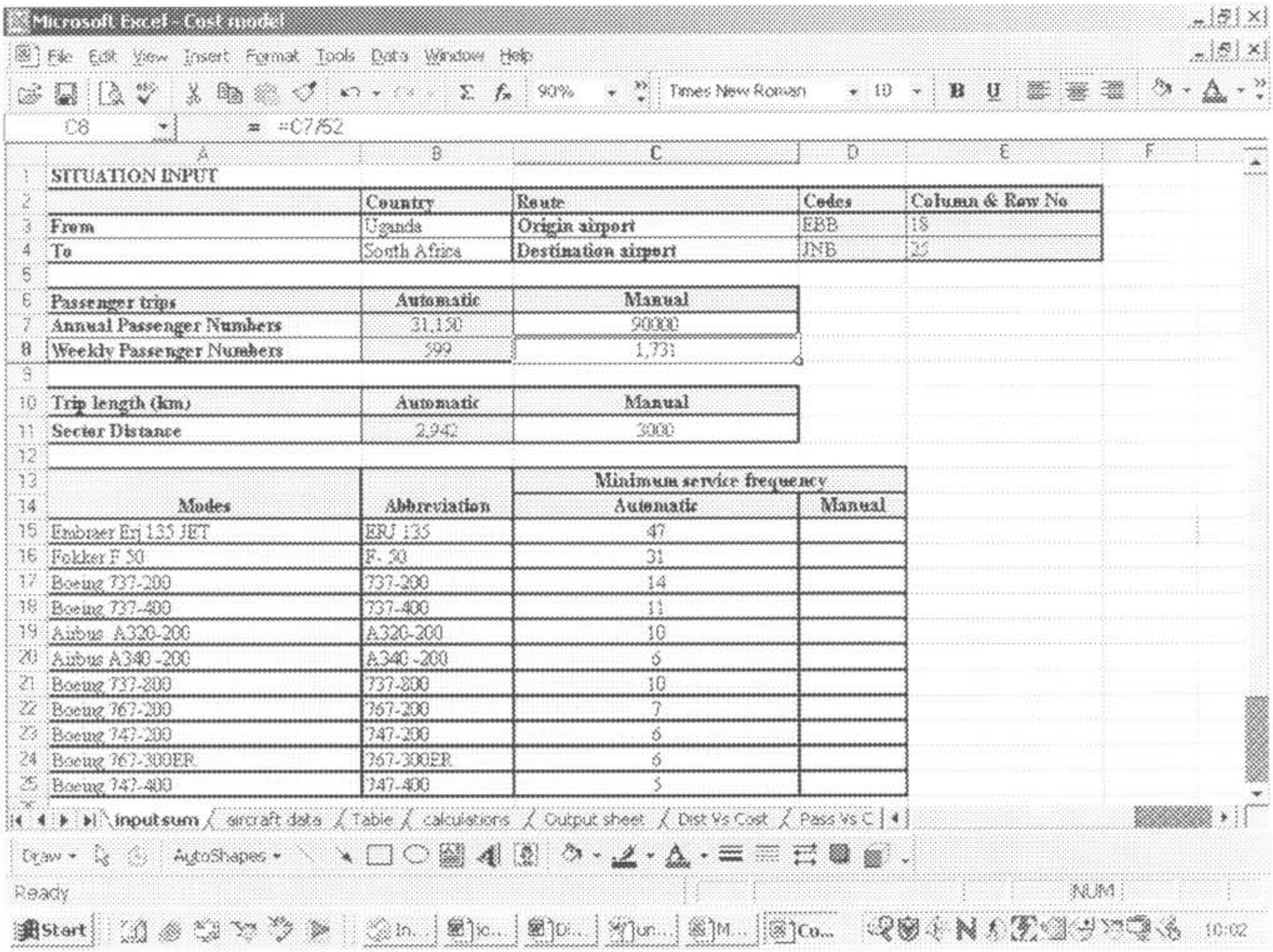
Minimum service frequency

This is defined in the model as the minimum number of flights required to meet the weekly passenger demand. There may also be a limit to the number of flights that a given route can be assigned, either according to regulations, politics or preference of the model user.

3.2.2 Africa databases

The model, in order to be applicable to the Africa situation, includes a 50 x 50 airport distance and the air passenger matrix. These sheets have been included in Appendices B and C respectively. The model will be such that it automatically picks information specific to the route characteristics that the user inserts for the route described.

Figure 7 shows an example of the input sheet for passengers travelling from Entebbe, Uganda, to Johannesburg, South Africa. The distances and passenger numbers are all input from the database. The different aircraft types used in the model are discussed in Chapter 4.



C6 = =C7/52

SITUATION INPUT

	Country	Route	Codes	Column & Row No
From	Uganda	Origin airport	EBB	18
To	South Africa	Destination airport	JNB	35

Passenger trips	Automatic	Manual
Annual Passenger Numbers	31,150	90000
Weekly Passenger Numbers	599	1,731

Trip length (km)	Automatic	Manual
Sector Distance	2,942	3000

Modes	Abbreviation	Minimum service frequency	
		Automatic	Manual
Embraer Erj 135 JET	ERJ 135	47	
Fokker F 50	F- 50	31	
Boeing 737-200	737-200	14	
Boeing 737-400	737-400	11	
Airbus A320-200	A320-200	10	
Airbus A340 -200	A340 -200	6	
Boeing 737-800	737-800	10	
Boeing 767-200	767-200	7	
Boeing 747-200	747-200	6	
Boeing 767-300ER	767-300ER	6	
Boeing 747-400	747-400	5	

Figure 7: Input Sheet

3.3 Calculation module

This sheet does all the calculations in the model. It compiles all the default data, input data and aircraft specifications that are necessary to calculate each cost component, for each aircraft type. Below are a description of all the components that are used in the calculation sheet, and the basis of the equations to calculate them. An extract of this worksheet is shown in Figure 8.

3.3.1 Route service characteristics

These characteristics describe the route over which the service is to be run and are used to calculate the sector flight time, frequency and utilization.

Minimum service frequency

These are the minimum number of passengers required to meet demand. It is calculated by dividing the passenger demand by the aircraft passenger capacity, and is found on the input sheet:

$$\text{Weekly aircraft trips} = \frac{\text{Weekly passenger Demand}}{\text{Aircraft passenger Capacity}} \quad \text{..................... 3-1}$$

Sector distance

This sector distance is given in the *input module*, as the route length distance from origin airport to destination airport and will be used to determine the block time for the aircraft.

Block time

This is calculated as the time taken for a given aircraft mode to fly over the route length specified in the input sheet. The block time takes into consideration the lost time as the aircraft is taking off and landing and in essence described as time from "engine-on" until "engine – off". The acceleration and deceleration time losses are assumed in the time specified for take-off and landing.

Round trip time

This time is different from block time in that it includes the entire time taken for a round trip. It includes the time taken for servicing and refueling before the aircraft can take off again at both ends. The duration of this service time, is taken as standard i.e. for larger aircraft, sufficient manpower is employed to achieve the same time as for smaller aircraft.

The flight time is calculated in the model using:

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$$\textbf{Round trip time} = 2\,(\textbf{Block time} + \textbf{servicing time}) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\text{3-2}$$

Maximum daily service frequency (supply)

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 can fly per day, which is included in the usable operating hours for each aircraft. Value must be rounded-off downwards i.e. 4,7 flights = 4 flights. The daily flight frequency is calculated as:

$$\textbf{Number of flights} = \textbf{Integer value of} \left[\frac{\textbf{Usable operating hours}}{\textbf{Block time} + \textbf{Servicing time}}\right] \qquad \ldots\ldots\ldots\ldots\ \text{3-3.}$$

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 one one-way flight a day, the maximum weekly number of flights is 6 flights, as only 3 return flights per week with one aircraft are possible.

Fleet size

The fleet size, which will be needed to meet passenger demand, depends on the weekly frequency per aircraft and the standby fleet. The aircraft are assumed to be traveling the route at full capacity There is a minimum and maximum frequency that an aircraft can fly, which is determined by the number of operating hours in a day, and the length of the flight. This is necessary, such that when any of the fleet is undergoing maintenance, there is an aircraft available. A stand by fleet of 2% is meaningless in respect of a fleet of less than 50 aircraft; but it implies that external aircraft could be leased or hired to account for this extra expense.

$$\textbf{Fleet size} = \frac{(\textbf{1+standby fleet}) * \textbf{weekly one-way passengers}}{(\textbf{Aircraft capacity} * \textbf{maximum weekly frequency})} \qquad \ldots\ldots\ldots\ldots\text{3-4}$$

Utilisation

For the model, the utilisation period is considered weekly and annually for calculation of the operating costs. Weekly utilisation is calculated as the product of weekly flight frequency and block time while annual utilisation is also a product of weekly utilisation and number of weeks in a year.

$$\textbf{Weekly utilization (hrs / week)} = \textbf{No of flights / week} * \textbf{block hours / flight} \qquad \ldots\ldots\ldots\ \text{3-5}$$

$$\textbf{Annual utilisation (hrs / year)} = \textbf{weekly utilisation} * \textbf{weeks / year)} \qquad \ldots\ldots\ldots\ \text{3-6}$$

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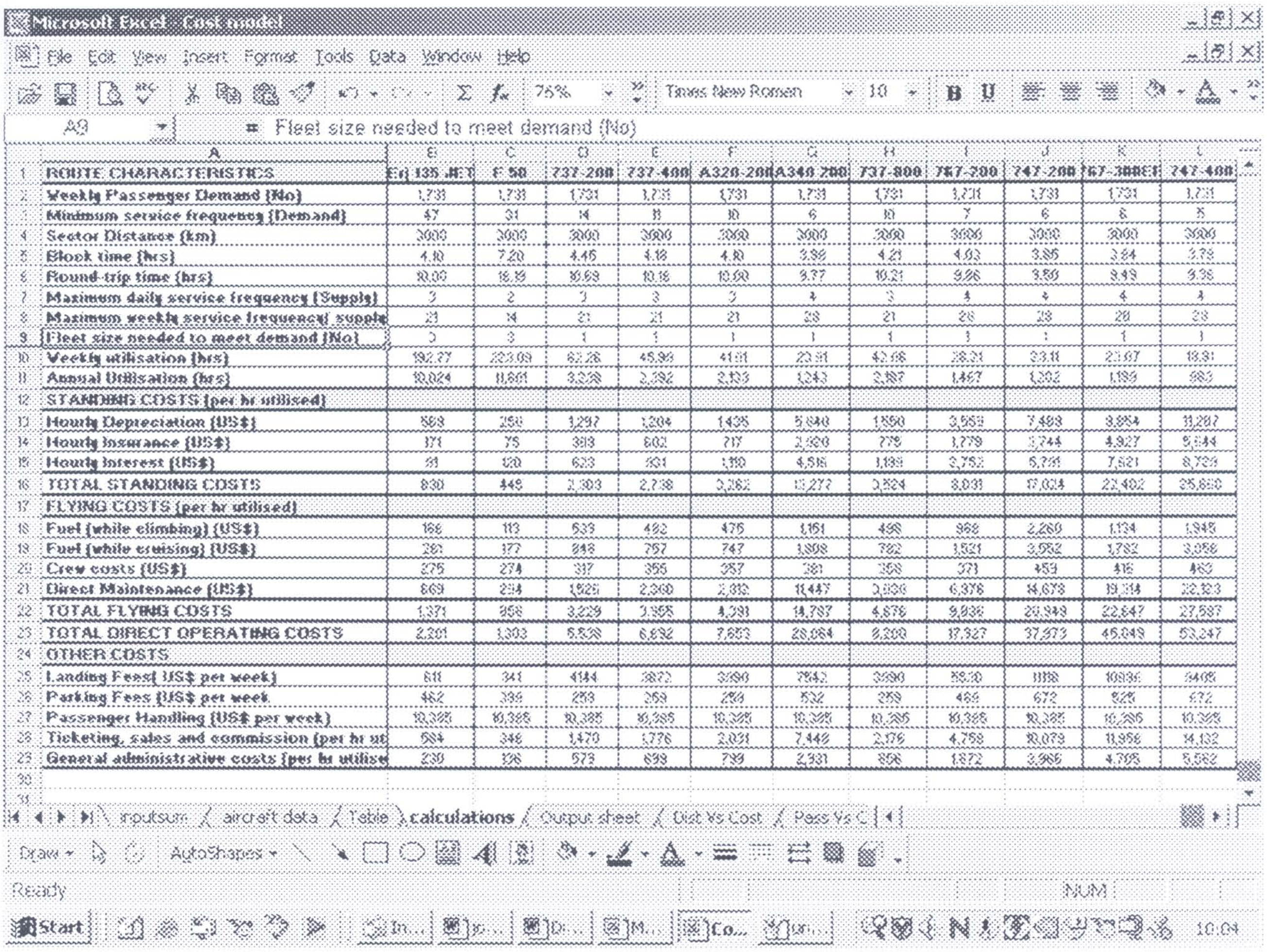
3.3.2 Operating costs

The aspects that are crucial in determining the operating costs, like fuel costs, wage levels, frequency of service, average length of haul and traffic density, will all be taken into consideration in the model for a service that is supposed to run cost effectively. The equations for the cost components under flying, standing and other costs used in the model are given in Table 14.

Figure 8 gives an example of the calculation sheet that appears in the model in the order that the calculations are done in the way that has been described above. The operating costs, which include the standing, flying and other costs in the calculation sheet are calculated using the equations in Table 14 in Chapter 2. The calculations are for the input sheet shown in Figure 7.



A9 = Fleet size needed to meet demand (No)

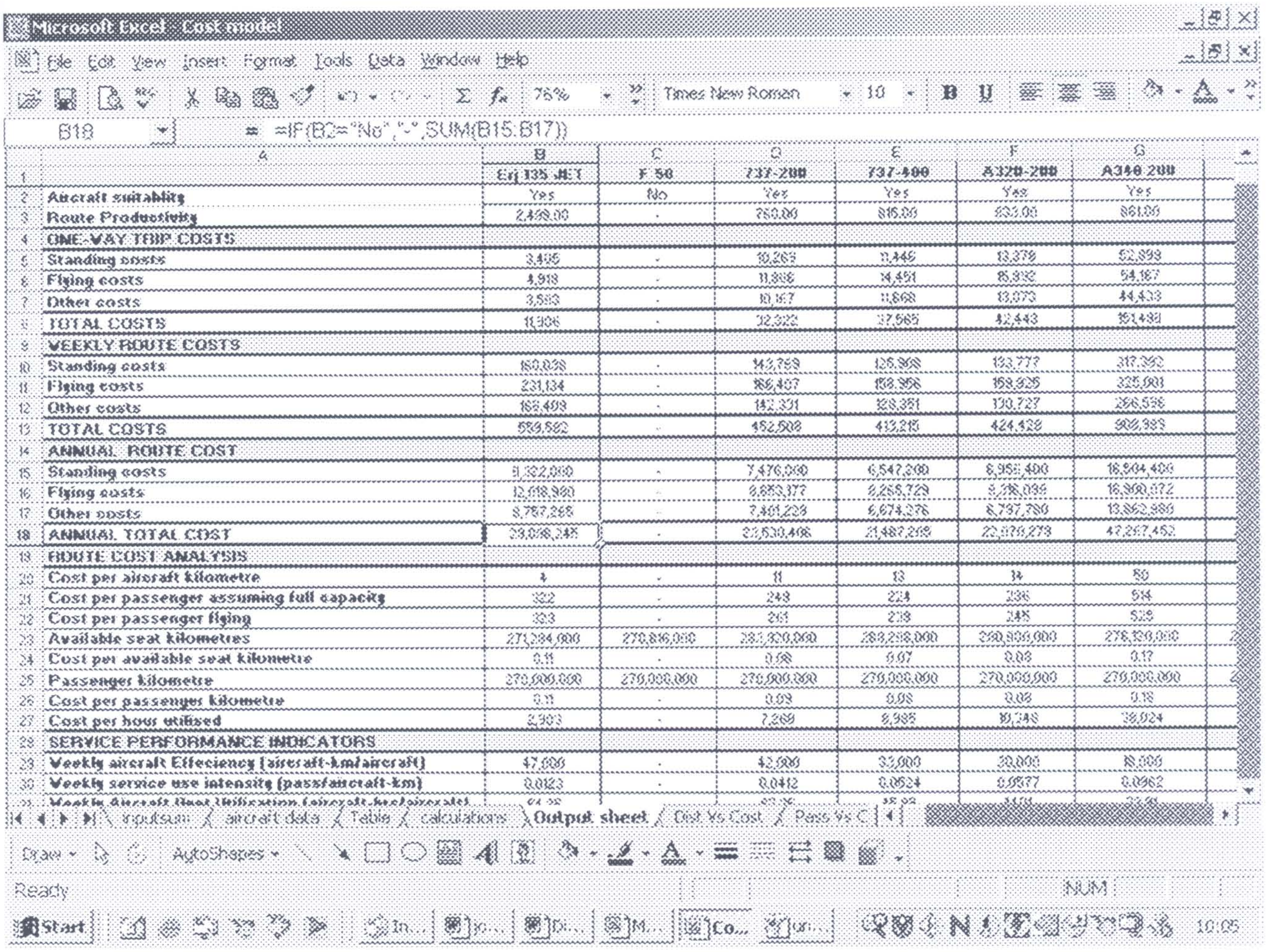
	A	B	C	D	E	F	G	H	I	J	K	L
1	ROUTE CHARACTERISTICS	Erj 135 JET	F 50	737-200	737-400	A320-200	A340 200	737-800	767-200	747-200	767-300ER	747-400
2	Weekly Passenger Demand (No)	1,733	1,733	1,733	1,733	1,733	1,733	1,733	1,733	1,733	1,733	1,733
3	Minimum service frequency (Demand)	47	31	14	11	10	6	10	7	6	6	5
4	Sector Distance (km)	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000	3000
5	Block time (hrs)	4.10	7.20	4.45	4.18	4.30	3.38	4.23	4.03	3.85	3.84	3.78
6	Round-trip time (hrs)	10.00	16.39	10.69	10.18	10.60	9.37	10.21	9.96	9.50	9.49	9.36
7	Maximum daily service frequency (Supply)	3	2	3	3	3	4	3	4	4	4	4
8	Maximum weekly service frequency(supply	21	14	21	21	21	28	21	28	28	28	28
9	Fleet size needed to meet demand (No)	3	3	1	1	1	1	1	1	1	1	1
10	Weekly utilisation (hrs)	192.77	223.09	62.26	45.98	41.41	23.91	42.06	28.21	23.11	23.07	18.91
11	Annual Utilisation (hrs)	10,024	11,601	3,238	2,392	2,153	1,243	2,187	1,467	1,202	1,199	983
12	STANDING COSTS (per hr utilised)											
13	Hourly Depreciation (US$)	583	253	1,297	1,204	1435	5,840	1550	3,559	7,488	9,854	11,287
14	Hourly Insurance (US$)	171	75	383	602	717	2,920	779	1,779	3,744	4,927	5,644
15	Hourly Interest (US$)	76	120	623	931	1,110	4,516	1,189	2,752	5,791	7,621	8,729
16	TOTAL STANDING COSTS	830	448	2,303	2,738	3,262	13,277	3,524	8,091	17,024	22,402	25,660
17	FLYING COSTS (per hr utilised)											
18	Fuel (while climbing) (US$)	166	113	533	482	475	1,161	498	968	2,260	1,134	1,948
19	Fuel (while cruising) (US$)	261	177	848	757	747	1,808	782	1,521	3,582	1,782	3,058
20	Crew costs (US$)	275	274	317	355	357	381	358	371	459	416	463
21	Direct Maintenance (US$)	669	294	1,925	2,360	2,812	11,447	3,038	6,376	14,648	19,314	22,123
22	TOTAL FLYING COSTS	1,371	858	3,623	3,954	4,391	14,797	4,676	9,236	20,949	22,647	27,587
23	TOTAL DIRECT OPERATING COSTS	2,201	1,303	5,926	6,692	7,653	28,074	8,200	17,327	37,973	45,049	53,247
24	OTHER COSTS											
25	Landing Fees(US$ per week)	611	341	4144	3872	3890	7842	3890	5830	8118	10936	9408
26	Parking Fees (US$ per week	462	339	253	259	256	532	259	469	672	828	672
27	Passenger Handling (US$ per week)	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385	10,385
28	Ticketing, sales and commission (per hr ut	584	348	1,470	1,776	2,031	7,449	2,176	4,759	10,079	11,956	14,132
29	General administrative costs (per hr utilise	230	136	573	698	799	2,331	858	1,872	3,985	4,705	5,582
30												
31												

inputsum / aircraft data / Table / **calculations** / Output sheet / Dist Vs Cost / Pass Vs C

Figure 8 Calculation sheet for model

3.4 Output module

The output sheet, in Figure 9, gives the overall performance indicators for the service that has been specified, for each aircraft type. It gives the overall indicators that will be used to determine the costs for the route specified.



B18 = =IF(B2="No","-",SUM(B15:B17))

	Erj 135 JET	F 50	737-200	737-400	A320-200	A340 200
Aircraft suitability	Yes	No	Yes	Yes	Yes	Yes
Route Productivity	2,458.00	-	760.00	816.00	833.00	861.00
ONE-WAY TRIP COSTS						
Standing costs	3,495	-	10,269	11,446	13,379	52,893
Flying costs	4,918	-	11,868	14,451	15,932	54,167
Other costs	3,583	-	10,167	11,668	13,073	44,433
TOTAL COSTS	11,996	-	32,323	37,565	42,443	151,493
WEEKLY ROUTE COSTS						
Standing costs	160,038	-	143,769	125,908	133,777	317,392
Flying costs	231,134	-	166,407	158,956	159,925	325,983
Other costs	168,409	-	142,331	128,351	130,727	266,538
TOTAL COSTS	589,582	-	452,508	413,215	424,428	909,383
ANNUAL ROUTE COST						
Standing costs	9,332,000	-	7,476,000	6,547,200	6,956,400	16,504,400
Flying costs	12,618,980	-	8,653,377	8,265,729	8,376,098	16,900,072
Other costs	8,787,268	-	7,401,228	6,674,276	6,737,780	13,862,980
ANNUAL TOTAL COST	23,038,248	-	23,530,406	21,487,205	22,070,278	47,267,452
ROUTE COST ANALYSIS						
Cost per aircraft kilometre	4	-	11	13	14	50
Cost per passenger assuming full capacity	322	-	248	224	236	514
Cost per passenger flying	323	-	261	239	245	529
Available seat kilometres	271,284,000	270,816,000	283,920,000	283,298,000	280,900,000	278,320,000
Cost per available seat kilometre	0.11	-	0.08	0.07	0.08	0.17
Passenger kilometre	270,000,000	270,000,000	270,000,000	270,000,000	270,000,000	270,000,000
Cost per passenger kilometre	0.11	-	0.09	0.08	0.08	0.18
Cost per hour utilised	2,303	-	7,269	8,985	10,248	38,024
SERVICE PERFORMANCE INDICATORS						
Weekly aircraft Effeciency (aircraft-km/aircraft)	47,096	-	42,996	33,000	30,000	18,000
Weekly service use intensity (pass/aircraft-km)	0.0123	-	0.0412	0.0524	0.0577	0.0962

Figure 9: Output Sheet

3.4.1 Mode selection

Technical specifications are given that determine whether or not a given aircraft is equipped to fly over a given sector distance. The specifications that determine this are the maximum range over which any given aircraft can fly. These two conditions will determine what modes can be selected. In the output, only the values for those modes that are appropriate are provided.

3.4.2 Route productivity

Vuchic (1981) states that the route productivity is defined as the time efficiency within which work is performed. The cost per route productivity (cost / aircraft-km/hr) reflects the difference in speed at which the service is operated, in any of the above stated units. It is calculated in the model as the product of the fleet size of aircraft on a given route and the average cruising speed. In the model it is calculated as:

$$\textbf{Cost per Route Productivity} = \frac{\textbf{Cost / hour}}{\textbf{Fleet size x Average speed of aircraft}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{3-7}$$

3.4.3 Cost components

For this study, the costs are to be calculated for the different aircraft for each of the parameters below:

- Costs for a round trip
- Weekly cost per aircraft, based on the frequency to meet demand
- Weekly cost of route
- Annual cost of route

In order to evaluate the cost of providing the airline service along a route, it is necessary to calculate the following parameters:

- Annual aircraft-km
- Annual available seat-km
- Annual passenger - km
- Route productivity (seat-km / hr)

In the model, the following five cost indicators are calculated using these parameters:

- Cost / passenger-km
- Cost / aircraft-km
- Cost / seat-km
- Cost / passenger
- Cost / aircraft-km / hr

3.4.4 Cost per passenger-km

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

$$\text{Cost / passenger-km} = \frac{\text{Cost per given time period}}{\text{Passengers x km (for same time period)}} \qquad \ldots\ldots\ldots\ldots 3\text{-}8$$

3.4.5 Cost per available seat-km

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 3-8 represent the passenger capacity for any given aircraft. The cost / available seat-km is a measure of the cost of providing the total quantity of service. This is calculated as follows:

$$\text{Cost / available seat-km} = \frac{\text{Costs per given time period}}{\text{Available seats x km (for same time period)}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3\text{-}9$$

3.4.6 Cost per aircraft-km

Aircraft-km is defined as the total distance flown by all the aircraft in the fleet, during a given time period. The costs per aircraft-km give a measure of how suited a specific aircraft is for the given route. It is calculated as:

$$\text{Cost /aircraft-km (for a time period)} = \frac{\text{Operating costs for the time period}}{\text{Aircraft-km travelled (for the same time period)}} \qquad \ldots\ldots\ldots\ldots 3\text{-}10$$

3.4.7 Cost per passenger travelling

Cost/passenger travelling is calculated as the total operating costs for a given service, along a route as a measure of how many people are using the service. It should be noted that passenger demand is seasonal; as such different costs could be determined for different periods of operation. These costs are calculated as:

$$\text{Cost per passenger travelling} = \frac{\text{Operating costs for service over the time period}}{\text{Number of passengers in the same time period}} \qquad \ldots\ldots 3\text{-}11$$

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4 CHAPTER FOUR: DATA COLLECTION AND ANALYSIS

4.1 Introduction

This chapter is a compilation of all data that was used in developing the cost model. The default values that have been compiled from references are elaborated upon, in the first part. The second part of the chapter deals with the translation of the data, into a format that can be applied to the present study.

4.2 Model default values

This information entails the background and discussion on which the specific values have been chosen.

4.2.1 Depreciation period

The depreciation period is the time within which an airline is charged for the expense of the flight equipment losing its value over time. The time that will be used in this study depends on the economic life of the aircraft and ever-changing technology, which may deem the aircraft obsolescent.

With this in mind, Doganis (1989) quotes that airlines have adopted a depreciation period of between 14-16 years for large wide-bodied jets and 8-10 years for smaller short-haul aircraft. For this study, average periods of 15 years and 9 years are used for the wide-bodied and small-bodied aircraft respectively.

4.2.2 Residual value

The residual value is a final worth of the total cost, of the aircraft at the end of its useful life; it is expressed as a percentage of the total cost.

The value quoted by Doganis (1989) as assumed by most airlines is 10 percent. This will be the residual value used in this study.

4.2.3 Interest rate

World Bank (2002), in the development indicator, especially for African countries, indicates that the interest rate, at which money is lent to governments, is 8%. This value used cuts across African countries with varying economic conditions i.e. foreign exchange rates, inflation, etc.

4.2.4 Annual insurance rate

The insurance premium paid out for each aircraft is calculated as a percentage of the full replacement price. This of course depends on the number of factors, which may include the number of aircraft, security and risk factors involved, geographical location, etc.

Doganis (1989) quotes that the value may range between 1,5-3 percent. As a measure to cut across African countries varying economic and security conditions, the annual insurance rate has been selected as 3 percent.

4.2.5 Lost time

There is a lot of time which the aircraft loses that is included in the block time, which is defined as the time from engine on to engine off. This time depends on factors like the traffic at origin and destination airports, weather conditions, mechanical state of the aircraft, size of the aircraft, security reasons, etc. The components of lost time are elaborated on below.

Ground manoeuvre time

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

Doganis (1989) and the Air Transport Association (1963) both state that unless it's a weather problem, the ground manoeuvre time does not exceed 30 minutes even for busy international airports and ranges between 20 - 30 minutes.

The African continent has a few busy airports e.g. Johannesburg International, Jomo Kenyatta International, Cairo International, etc, with average headways of even less 10 minutes per landing. For the purpose of this study, the average time for ground manoeuvre is taken to be 20 minutes.

Air manoeuvre time

The air manoeuvre time is defined as the time the aircraft takes to climbs 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 the time the aircraft burns most fuel and travels at relatively lower speeds. On short sectors, most of the flight time is covered either in 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 to be about 6 minutes. This value will be used in the model.

Servicing time

When the engine of an aircraft are switched off, and the passengers depart from the aircraft, the aircraft has to undergo a number of activities that can be carried out simultaneously. The activities include servicing of the engines, Check A which involves detecting abnormalities with the system, leakages, refueling if necessary especially for long journeys, cleaning, restocking of foods and beverages, passenger loading, etc.

Kulula Airlines is a low-cost, short haul, domestic air carrier in South Africa that minimises costs by utilising an aircraft with minimal fleet and maximum frequency for any given route. The route schedule for the Johannesburg to Cape Town route for the 25th April 2003 is shown in Table 15. It will be used to show the "servicing" times derived. (Kulula Airlines, 2003)

Table 15: Flight schedule for JBG- CPT route for Kulula.com

Flights from Jo'burg to Cape Town	**Departure time**	**Arrival time**
25 Apr 2003	0630	0840
25 Apr 2003	0925	1130
25 Apr 2003	1100	1305
25 Apr 2003	1220	1425
25 Apr 2003	1515	1720
25 Apr 2003	1810	2015
Flights from Cape Town to Jo'burg	**Depart**	**Arrive**
25 Apr 2003	0630	0825
25 Apr 2003	0925	1120
25 Apr 2003	1220	1415
25 Apr 2003	1400	1555
25 Apr 2003	1515	1710
25 Apr 2003	1810	2005

Source: Kulula airlines (2003)

Table 16 shows the servicing times derived from Table 15.

Table 16: Aircraft servicing time.

	Departs	Arrives	Depart	Arrives	Departs	Arrives	Departs	Arrives	Departs	Arrives
	JHB	CPT	CPT	JHB	JHB	CPT	CPT	JHB	JHB	CPT
Aircraft 1	0630	0840	0925	1130	1220	1425	1515	1720	1810	2015
Servicing time (min)		45		60		50		60		
	CPT	JHB	JHB	CPT	CPT	JHB	JHB	CPT	CPT	JHB
Aircraft 2	0630	0825	0925	1120	1220	1415	1515	1720	1810	2005
Servicing time (min)		60		50		60		50		
			JHB	CPT	CPT	JHB				
Aircraft 3			1100	13.05	1400	1555				
Servicing time (min)				55						

From Table 16, the average servicing and refueling time is calculated for all the aircraft to give a default value of 54 minutes. This time will also be assumed for larger aircraft, for which more manpower will be used.

4.2.6 Usable operating hours

Stratford (1973) suggests that, for any given aircraft to be utilized efficiently in a bid to spread out operating costs over its useful life, it will be in use for a maximum of 14 hours in any operating day, whether daytime or nighttime. This means that the frequency, over which an aircraft should be used, will depend on the flight time and will be dictated by the usable hours in a day. In a year, the aircraft will be assumed to be in use for 52 weeks.

4.2.7 Fuel and oil

Emery (2002), gives the average cost of fuel prices for the African situation for 2002 prices in Table 5. Therefore the default price value of fuel of US$ 0,895/US gal will be used for the model. Turbo jet technologies (2002), gives the cost of oil as US$ 0,233/ US gal. The fuel to oil ratio that will be used is 20:1 adopted from the Turbine design website.

4.2.8 Passenger demand within Africa

On the African Airline Association (AFRAA) web site, the 1999 Annual Report gives a summary of the air traffic movements and growth rates for Africa. The report states that system wide in 1999 airlines carried 29,6 million passengers representing a 3% growth over 1998.

Of these, 11,4 million passengers were flying within the domestic market, 4,3 million and 13,9 million passengers were flying within Africa and on international markets respectively.

Table 17 shows the number and percentage of passengers carried in the various markets between 1994 and 1999. The number of passengers moving within the Africa region, as a percentage of passenger demand is 15%. This average value may not be representative because it could include the passengers who flew within Africa via Europe, but will be taken as 15 % for the purposes of this study.

Table 17: African air travel passenger percentages

Year	Domestic (Millions)	Domestic (%)	Within Africa (Millions)	Within Africa (%)	International (Millions)	International (%)
1994	10,8	43	3,1	12	11,5	45
1995	11,6	44	3,0	11	12,0	45
1996	12,4	44	3,5	13	12,3	43
1997	12,1	42	3,6	13	13,0	45
1998	11,5	46	4,1	14	13,1	40
1999	11,4	39	4,3	15	13,9	46

Source: AFRAA annual report 2000

4.2.9 Summary

Table 18 gives a summary of the default values that will be used in the model, specified for different aircraft types, giving references for their sources:

Table 18: Default values used in the model

ITEM	DEFAULT VALUES	REFERENCE
Depreciation period (years)	9	Doganis (1989)
Residual value (%)	10	Doganis (1989)
Interest rate (%)	8	World Bank (2002)
Annual insurance rate (%)	3	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 (2002)
Average international air passengers moving within Africa region (%)	15	AFRAA (2000)

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4.3 Aircraft types

Aircraft types to be compared need to be applicable to the present aviation industry. Data relevant to the African industry was collected and the most common aircraft types were chosen. The aircraft to be considered will include short, medium and long haul aircraft, which fly all routes within Africa.

A report "Who Operates What" by Air Claims Limited, UK in the African Aviation magazine (June 2000) contained data on Africa's major airlines and their fleets. The 40 most common aircraft types were chosen and then narrowed down to the 11 aircraft modes from "in-flight" magazines from airlines that fly over wide regions within Africa. These airlines include South African Airlines (2002), Kenya Airways (2003) and British Airways (2002).

4.3.1 Aircraft specifications

In order to calculate the cost of running the chosen aircraft, technical specifications were collected. The detailed specifications for each of the aircraft chosen are shown below, with their sources:

- Cruising speed, (Jackson 1997)
- Passenger Capacity, (Jackson 1997)
- Engine type, Number, Thrust, (Turbine design Inc.2003, Rolls Royce 2003)
- Max fuel Capacity, (Jackson 1997)
- Crew Number, (Jackson 1997)
- The Maximum Take-off Gross weight (ToGWmax), (Jackson 1997)
- Maximum range, (Jackson 1997)

4.3.2 Engine Specifications

Jenkinson et al (2001) gives aircraft data for different aircraft types and engines. This data will be used to calculate the amount of fuel and oil consumption for each engine type during climbing, descent and cruising. Table 19 gives engine data for different jet aircraft.

Table 19: Aircraft engine data

Aircraft Type	**Fokker F28**	**Boeing 737-200**	**Boeing 737-300**	**Airbus A320**	**Airbus A340-200**	**Boeing 747-200**	**Boeing 757**	**Boeing 747-400**	
Engine type	**RB 183 555**	**JT15D**	**CFM 56 -3C1**	**V2500-A1**	**CFM56 -5C2**	**RB211 -524H**	**RB211-535E4**	**CF6 80 C2-B2**	**Average % Change**
Thrust	9 900	16 000	23 500	25 000	31 200	60 600	43 100	52 500	
Climb Thrust		3 045		5 070		11 813	9 110	12 650	
% Change max'm to climb		19,0%		20,3%		19,5%	21,1%	24,1%	21%
Cruise thrust	3 730	2 414	5 540	5 620	7 580	12 726	8 495	12 000	
% Change max to cruise	37,7%	15,1%	23,6%	22,5%	24,3%	21,0%	19.7%	22,9%	22%
SFC (lb/hr/lb)									
Engine SFC (lb/hr/lb)	0,56	0,56	0,33	0,35	0,32	0,563	0,607	0,32	
Cruise SFC (lb/hr/lb)	0,8	0,541	0,667	0,581	0,545	0,57	0,598	0,576	
% Change from engine to cruise	142,9%	96,6%	202,1%	166,0%	170,3%	101,2%	98,5%	180,0%	150%

From the data averages, an aircraft climbs with thrust on average of about 21% of the maximum engine thrust with the engine SFC. At cruising, the thrust reduces from the maximum thrust by about 22% but the cruising SFC increases to 150% of the engine SFC.

The reason why SFC is lower at take off than at cruising was suggested in an aviation website (Airliners.net (2003)) that "the lower SFC at Take Off thrust is due to higher thermal efficiency as the engine is running hotter, but it can't be maintained at this condition continuously while the cruise thrust can".

For the model, fuel consumption during air maneuver and cruising will be separated and different calculations using equation 2-16 with thrust and SFC dependant on whether the aircraft is cruising or during air manoeuvre, before descent. Air manoeuvre time is assumed 15 minutes to include both climbing and descending from cruising irrespective of the politics surrounding the altitude that an aircraft will fly and degrees of freedom.

4.4 Capital costs

Pyramid Media Group is an online air guide website with information on the aviation industry. It gives the average aircraft prices for the most common aircraft from 1997-2001. Table 20 shows the aircraft prices that are relevant to this study. Even though a projection could be done of 2003, since the prices seem to be increasing by 2%, unaccountable factors like increased security specifications of aircraft since 9/11 could have changed this rate, therefore year 2000 prices will be used in the study. For the values of the year 2000 that were missing, the last representative price was used instead.

Table 20: Capital costs for aircraft types

Capital (US$ mil)	Embraer Erj135-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
1996	-	-	41	45	-	-	51	82.5	-	-	165
1997	-	-	41,5	45	-	99	51,5	82	-	-	168
1998	-	-	-	46,5	-	106	54	-	-	-	176
1999	-	-	-	47,25	-	113	55,25	-	-	-	180
2000	19	29	-	48	51	121	56,5	-	-	-	185

Source: Pyramid Media Group Website (2003)

4.5 Airport handling fees

The airport charges which include the passenger service fee, landing fee and airport fee used in this study are those applied by the Airports Company South Africa (ACSA), stemming from the fact that it is the only available data.

These may not be applicable to most African countries since South Africa has one of the busiest African airports, Johannesburg International airport. The data was originally stated in the Airports Company Act 1993 (Act No. 44 of 1993) it was later amended and can be found in the Airports Company Amendment Act 1998, (Act No. 2 of 1998). The rates in the Act were in South African Rand, but for this study they have been changed to US$ using the rate for May 2003 at ≈ 8 Rand to the US dollar.

4.5.1 Passenger service fee

The passenger service fee according to this act is charged per embarking passenger. Table 21 is an excerpt from Annexure C of the Airports Company Amendment Act (2 of 1998), that provides tariffs, and fees that can be applied.

The value that was adopted for the study is that for passengers disembarking from the aircraft at an airport outside South Africa, Botswana Lesotho, Namibia or Swaziland. This value is therefore assumed to be US$ 6 per passenger in Africa, an average of the cost of passenger handling assuming that deregulation within the African continent will stipulate lower costs for passengers flying from one African country to another.

Table 21: Passenger service fees

Specifications	VAT		
	Exclusive	**Inclusive**	
	R	**R**	**US$**
Passenger service charge per embarking passenger where such passengers will disembark from the aircraft at an airport within the Republic of South Africa	19,30	22,00	2,75
Passenger service charge per embarking passenger where such passengers will disembark from the aircraft at an airport within Botswana, Lesotho, Namibia or Swaziland	40,35	46,00	5,75
Passenger service charge per embarking passenger where such passengers will disembark from the aircraft at an airport within any state or territory other than those mentioned in paragraphs 1 and 2	**59,65**	**68,00**	**8,50**

Source: Airports Company Act, 1998 (Act No. 2 of 1998)

4.5.2 Landing fees

The landing and parking fees according to this act are based on the Maximum Take Off Weight (MToW) of the aircraft concerned. Table 22 shows an excerpt of Annexure A of the Act, weight specific charges for "landing charges in respect of an aircraft which lands at an ACSA airport and which has been engaged in a flight where the airport of departure of the aircraft was not "within South Africa, Botswana, Lesotho, Namibia or Swaziland". These charges are applied to determine the landing charges for each aircraft considered in the model.

Table 22: Weight specific landing fees

MTOW (kg) of the aircraft (Up to and including)	Per single landing		
	VAT		
	Exclusive	Inclusive	Total
	R	R	US$
5 000	23,68	27	3,38
10 000	38	43,32	5,42
15 000	57,18	65,18	8,15
20 000	74,42	84,84	10,61
25 000	92,03	104,91	13,11
30 000	110,12	125,54	15,69
40 000	148,6	169,41	21,18
50 000	186,11	212,17	26,52
60 000	223,27	254,53	31,82
70 000	261,03	297,57	37,20
80 000	298,05	339,78	42,47
90 000	335,94	382,97	47,87
100 000	373,94	426,29	53,29
And thereafter, for every additional 2 000kg	65,43	74,59	9,32

Source: Airports Company Act, 1998 (Act No. 2 of 1998)

4.5.3 Parking charges

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The parking charges in the Act are also weight specific and are incurred after an initial free four-hour period while charges are allocated per 24-hour period. Table 23 is an excerpt from Annexure B of the Airports Amendment Act giving the specified charges per weight.

Table 23: Weight specific parking fees

MTOW (kg) of the aircraft (Up to and including)	**Per 24 hr period**		
	VAT		
	Exclusive	**Inclusive**	
	R	**R**	**US$**
2 000	13,23	15,08	1,89
3 000	27,2	31,01	3,88
4 000	38,73	44,15	5,52
5 000	53,18	60,63	7,58
10 000	78,3	89,26	11,16
15 000	102,96	117,37	14,67
20 000	129,79	147,96	18,50
25 000	154,92	176,61	22.13
50 000	204,94	233,63	29,20
75 000	255,08	290,79	36,35
100 000	305,83	348,65	43,58
150 000	384,74	438,60	54,83
200 000	464,27	529,27	66,16
300 000	530,8	605,11	75,64
400 000	668,55	762,15	95,27
And thereafter, for every additional	102,96	117,37	14,67

Source: Airports Company Act, 1998 (Act No. 2 of 1998)

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4.6 Summary

The data that has been collected and analysed, in a form that will be applicable to the cost model being developed is summarised in Table 24.

Table 24: Data summary for aircraft types

AIRCRAFT 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
Cruising Speed (Kph)	833	448	760	815	833	861	810	850	895	897	914
Passenger Capacity	37	56	130	168	180	295	189	255	291	290	401
ToGWmax (Kg)	21 100	19 950	52 437	68 040	73 500	27 500	78 240	136 985	374 850	181 890	390 100
Max fuel Capacity (US gal)	5 187	1 357	5 163	5 701	6 300	3 6984	6 878	16 700	53 858	24 140	48 445
Engine type	AE3007	PW125B	JT8D-15A	CFM 56-3B-2	CFM56-5A3	CFM56-5C2	CFM56-7B24	CF6-80A	RB211-524D4	CF6-80C2B6F	PW 4056
Engine maximum thrust (Ibf)	7 400	5 000	16 000	22 000	25 000	31 200	24 000	48 000	53 000	61 500	47 000
Engine SFC (Ib/hr/Ibf)	0,39	0,391	0,585	0,38	0,33	0,32	0,36	0,35	0,37	0,32	0,359
Cruise SFC (Ib/hr/Ibf)	0	0	0	0	0	0	0	0	0	0	0
Maximum range (km)	3 019	1 300	3 700	3 810	5 615	13 500	5 670	12 250	7 900	12 500	13 480
Number of Engines	2	2	2	2	2	4	2	2	4	2	4
Crew Number	5	5	6	7	7	8	7	7	8	8	8
Capital Cost of aircraft (US$ million)	19	29	42	48	51	121	57	87	150	197	185
Change from engine thrust to climb thrust (%)	21	21	21	21	21	21	21	21	21	21	21
Change of engine thrust to cruise thrust (%)	22	22	22	22	22	22	22	22	22	22	22
Change from Engine SFC to Cruise SFC (%)	150	150	150	150	150	150	150	150	150	150	150
Fuel consumption during air manoeuvre (US gal/hr)	180,91	122,55	586,75	524,06	517,16	1251,73	541,61	1 053,13	2 458,57	1 233,67	2 115,42
Maximum cruise Fuel Consumption (US gal/hr)	284,29	192,58	922,03	823,52	812,69	1 967,00	851,10	1 654,93	3 863,46	1 938,63	3 324,23
Oil consumption climbing (US gal/hour)	9,05	6,13	29,34	26,20	25,86	62,59	27,08	52,66	122,93	61,68	105,77
Oil consumption cruising (US gal/hour)	14,21	9,63	46,10	41,18	40,63	98,35	42,56	82,75	193,17	96,93	166,21
Passenger service charge (US$)	6	6	6	6	6	6	6	6	6	6	6
Landing Fees (US$ per single landing)	13	11	296	352	399	1257	399	790	1853	1816	1881
Parking Fees (US$ per 24 hour period)	22	19	37	37	37	76	37	67	96	75	96

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5 CHAPTER FIVE: MODEL ANALYSIS

5.1 Introduction

This chapter deals with how the route cost model, can be applied to the following analyses for running an airline service:

- Route analysis
- Varying distance analysis
- Varying passenger analysis

5.2 Route analysis

The analysis that can be carried out along a route, will involve different aspects of the service being provided. They include: route cost analysis, service analysis, service efficiency and utilisation indicators, which are all calculated in the output sheet of the cost model.

5.2.1 Route cost analysis

The model calculates the cost involved in running an airline service along a route. The cost model can be applied to analyse the operating costs, for specified input components of distance and passenger numbers. For a given route, the output components are used to make a choice on the most suitable service, on the basis of the different cost indicators, the type of aircraft, etc.

Table 25 is a summary of annual flight cost indicators for the aircraft types that can provide a service along the specified route of sector distance 3 249 km and 30 000 passenger per year. Three aircraft within 10% of the least cost within the margin accuracy of the model will be highlighted. The conclusions inferred from Table 25, are only applicable to this specific route. The aircraft that are not included are eliminated by the model because of the maximum range they can fly.

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Table 25: Cost indicators for given aircraft type (US$)

Aircraft type	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
Cost per aircraft-km	23	27	29	130	32	64	164	208	199
Cost per passenger (At 100% load factor)	576	531	522	1 432	548	819	1 827	2 334	1 607
Cost per passenger (At ruling load factor)	650	618	652	1 465	719	1 086	1 843	2 347	2 236
Cost per available Seat-km	0,18	0,16	0,16	0,44	0,17	0,25	0,56	0,72	0,49
Cost per passenger-km	0,20	0,19	0,20	0,45	0,22	0,33	0,57	0,72	0,69
Cost per hour utilised	15 695	19 869	21 362	98 876	22 964	48 298	128 708	164 208	159 092

Costs per aircraft-km

On analysing Table 25, in terms of cost of the service per aircraft-km, the most cost-effective aircraft to run on the route include the Boeing 737-200 and 737-400 and the Airbus A320-200.

Costs per passenger (assuming full capacity)

This gives which aircraft is the cheapest to run when it is full during the peak season. In this case the aircraft that will be the cheapest to run is the Airbus A320-200, followed by the Boeing 737-400 and 737-800.

Costs per passenger flying

The annual cost for passengers flying i.e. the cost to meet demand, is done cheapest in the Boeing 737-400 followed by the Boeing 737-200 and the Airbus A320-200.

Cost per available seat-km

This gives the cost for the service provided, regardless of passenger numbers. In this case, the most economical aircraft to provide a service (supply) along this route is the Boeing 737-400; the Airbus A320-200 and Boeing 737-800 are also viable options.

Costs per passenger- km

The utilised output which is a measure of the service provided, in terms of the average distance moved by the passengers gives the Boeing 737-400 as the one with the lowest running costs, while both the Boeing 737-200 and the Airbus A320-200 compete favorably.

Cost per hour utilised

This is a measure to show which aircraft costs less for the hours utilised. The most economic aircraft type includes the Boeing 737-200, then the Boeing 737-400 and the Airbus A320-200.

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From the above indicators, it can then be seen that for any specific route depending on what the target of the airline service provider is, there is choice of what aircraft that can be used, without negotiation the quality of service provided. For this route in particular, the aircraft that can be chosen include: Boeing 737-400, Boeing 737-200, Airbus A320-200, and the Boeing 737-800 in no particular order of preference.

5.2.2 Service analysis

For the same route of sector distance 3 249km and 577 weekly passengers, the type of service being provided can be analysed. Various performance indicators shown in Table 26 are used to analyse transport services. These indicators are a measure of how the transport service can be run to minimise the operating costs, to a minimum. In terms of aircraft efficiency, service use intensity, work utilisation and aircraft fleet utilisation, the higher the indicator value, the more favorable the aircraft type used.

Table 26: Service performance indicators for the airline service

Service Performance Indicators	**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 aircraft efficiency (Aircraft-km/aircraft)	16 245	12 996	12 996	6 498	12 996	9 747	6 498	6 498	6 498
Weekly service use intensity (pass/aircraft-km)	0,0355	0,0444	0,0444	0,0888	0,0444	0,0592	0,0888	0,0888	0,0888
Weekly aircraft fleet utilisation (aircraft-hrs/aircraft/wk)	23,88	17,95	17,60	8,55	18,05	12,97	8,26	8,24	8,11
Work utilisation co-efficient (pass/seat)	0,89	0,86	0,80	0,98	0,76	0,75	0,99	0,99	0,72

Service efficiency indicators

For a given transport service, the following indicators are a measure of how efficiently different items in the service are being run. This can be used to identify components where interventions can reduce costs. These indicators are obtained as ratios of various measures of output to resources consumed. Analyses for efficiency indicators that can be applied to the model are defined below:

1. **Aircraft efficiency**

   This is defined as the measure of efficiency of how the aircraft in a fleet is being used. It's computed by dividing the total annual aircraft-km by the fleet size, the units given as aircraft-km/ aircraft/ year. This performance indicator will come into play for routes with high passenger volumes, which will need larger fleet sizes to meet the demand. Its unit is aircraft-km/aircraft/year. The higher the value is, the more efficiently the aircraft being used.

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2. Service use intensity

This is defined as the amount by which the passenger demand utilises the transport service. It is the ratio of the annual passengers to the annual aircraft-km travelled units is passengers/ aircraft-km. A high ratio implies that the service is being used optimally. This service intensity can also be measured by use of the load factor, which is calculated by calculating the ratio of the passenger-km to the seat-km.

Service utilisation indicators

The utilisation indicators can be applied to different items in transport service operations, to give a measure of how efficiently the service providers utilise these specific items. Some of these items include; fleet, capacity, work and labour. The indicators elaborated on below will only include those that will be reflected by the model; namely

1. Aircraft fleet utilisation

This gives the ratio of the sum of the operating hours of all aircraft to fleet size. It is further defined, as the average percentage of hours when aircraft are in use during an operational day, where the operational day period, is not 24 hours but the maximum number of hours an aircraft can be in use. The units of this indicator in the model are aircraft-hours/ aircraft/week.

2. Work utilisation coefficient

The Boeing 747-200 and 767-300ER have a high load factor of 0.99 in Table 4 due to fewer flights resulting from larger capacity aircraft. On the other hand, these aircraft have very high utilisation costs per aircraft-km in Table 3 of US$164 and US$208 respectively. This implies therefore that the load factor needs to be taken into consideration after evaluating the operating costs of the aircraft. For example the Boeing 737-200 costs US$ 23 per aircraft-km and has a relatively high load factor of 0,89 in Table 4 and would have cheaper operating costs.

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5.3 Effect of distance

The model also allows the user to vary the length of the route while keeping the passenger numbers constant. This worksheet can be used to calculate how increasing distance affects airline service costs for each aircraft type.

5.3.1 Route service operations

Since distance and block time are directly related, an increase in distance will increase the block time for each flight. The effect of the increasing distances on an airline service is summarised in Table 27.

It shows the service characteristics, for a weekly passenger demand of 1000 with varying distances for the Embraer Erj 135-Jet with passenger capacity of 37. It shows that as the distance increases so does the block time for each flight, lowering the number of flights each aircraft can fly per week. Consequently, the fleet capacity needed to meet demand; increases with increasing distance, and the values calculated are rounded up for purposes of stand-by fleet.

Table 27: Service variations with Distance

Distance (km)	Block time (hrs)	Maximum weekly trips per aircraft (Capacity)	Minimum weekly aircraft trips (Demand)	Fleet size (No)
200	0,59	35	28	1
400	0,83	28	28	1
600	1,07	21	28	2
800	1,31	21	28	2
1 000	1,55	21	28	2
1 200	1,79	14	28	2
1 400	2,03	14	28	2
1 600	2,27	14	28	2
1 800	2,51	14	28	2
2 000	2,75	7/14	28	2/4
2 200	2,99	7	28	4
2 400	3,23	7	28	4
2 600	3,47	7	28	4
2 800	3,71	7	28	4
3 000	3,95	7	28	4

Inferences from Table 27

- *Maximum weekly trips per aircraft are calculated according to block time and available aircraft utilisation. Under utilisation of an aircraft implies that, the minimum weekly aircraft trips to meet the passenger demand will be less than the maximum trips each plane can fly.*

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- *The fleet size along the route is calculated and rounded up to meet passenger demand and is inclusive of 2% stand-by fleet but can refer to cost of leasing a aircraft for short periods.*
- *For a aircraft flying less than 200 km there is no need to refuel in between flights for an operational day*

5.3.2 Effect of frequency specifications

In order to be able to choose the aircraft that can fly most efficiently in terms of costs along a given route, the worksheet for varying distances can be used to calculate costs along given routes. The costs for each aircraft type are plotted for constant distance and passenger numbers. This mode of application comes in handy when an airline service has various aircraft types and needs to choose which type flies more efficiently over the route.

Table 28 shows the fleet size, weekly trips and total operating costs that will be needed to run the airline service along the route length of 3 249km with a weekly passenger demand of 577 passengers.

Table 28: Service changes with varying aircraft types

Manufacturer	Aircraft type	Seat capacity	Fleet size	Weekly return trips	Operating costs (US$)
Embraer	**Erj 135-JET**	37	1	16	177 855
Fokker	**F 50**	56	No	No	No
Boeing	**737-200**	130	1	5	334 570
Boeing	**737-400**	168	1	4	323 336
Airbus	**A320-200**	180	1	4	341 816
Airbus	**A340 200**	295	1	2	781 282
Boeing	**737-800**	189	1	4	377 037
Boeing	**767-200**	255	1	3	572 249
Boeing	**747-200**	291	1	2	978 685
Boeing	**767-300ER**	290	1	2	1 256 390
Boeing	**747-400**	401	1	2	1 192 674

From Table 28 the following can be deduced:

- Because of the maximum range limitations, the Fokker F50 is not well suited for this journey type; its maximum range is 1 300 km.
- The more frequently an aircraft flies, the higher the operating costs. But in case of the 37-seater the Embraer Erj 135-Jet that flies 8 times more than the Boeing 747-400, has operating costs, which are one eighth of the larger aircraft. This is the basic principle used by low-cost air carriers flying low capacity planes over short distances at high frequencies.
- For flight frequencies that airport slots, airlines or governments could dictate, the choice of cheapest aircrafts can still be done. For a specific frequency of 2 flights a week, the A340-200 would be the cheapest aircraft to use, while for a frequency of 4 flights a week, the Boeing 737-400 would fly at the cheapest cost.

5.4 Effect of passenger numbers

The number of passengers can also be varied in a separate cost model sheet and the effect is generally that increasing the number of passengers, especially for the same route results in an increase in fleet size and operating costs.

5.4.1 Aircraft choice

The worksheet was set up to vary passenger numbers and then calculates operating costs for the different aircraft, allowing for a choice of the most economic aircraft to use, for specific passenger numbers. It doesn't take into consideration the maximum ranges the aircraft can fly.

Figure 10, shows the operating costs for flying a route length of 3 000 km with weekly passenger demand of 1 000 passengers. For the Erj 135 JET, a 37- seater, it can be seen that the operating costs are low, because even though the flight frequencies are high so as to meet passenger demand, cost per passenger is the lowest. The question then becomes whether or not the aircraft can fly the given route and at what frequency. For this particular route, the aircraft most suited for this route include the Boeing 737-400, 737-200 and the Airbus A320-200.

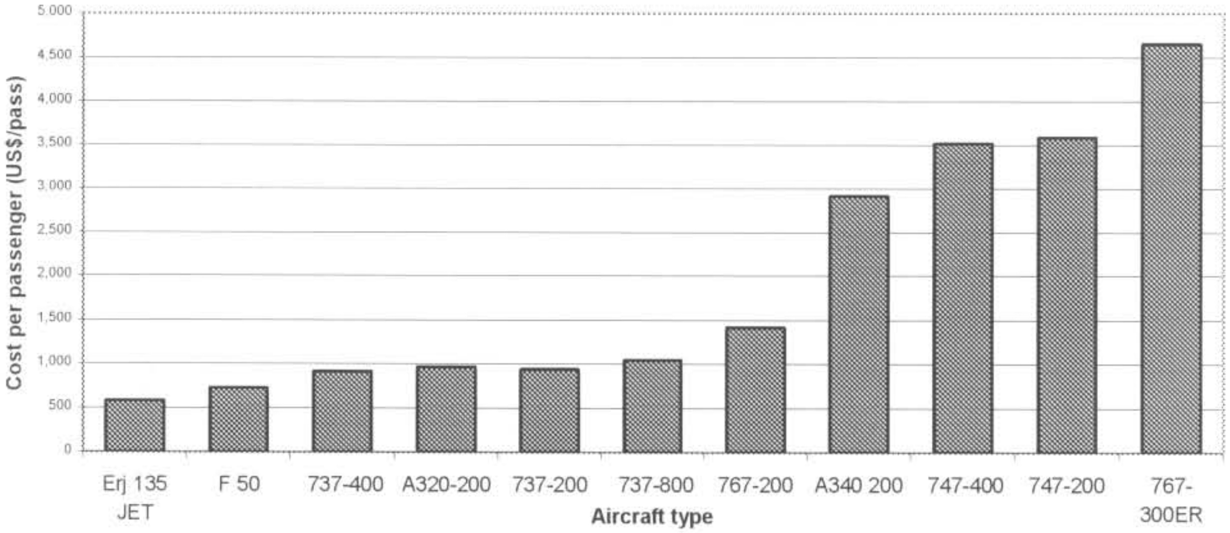

Figure 10 Operating cost per passenger for different aircraft types

5.4.2 Cost per passenger

Figure 11, shows that the cost per passenger for the different aircraft modes, decreases with increasing passenger demand. As verified in the literature review, the cost per passenger has a general trend of a decreasing exponential curve, as the passenger numbers increase. This is due to the fact that operating costs are incurred per passenger, so as passengers increase the operating cost reduces since it is spread over more people, who are paying for the service. The discontinuities in the curve are because of the cost of increasing fleet size, to meet demand.

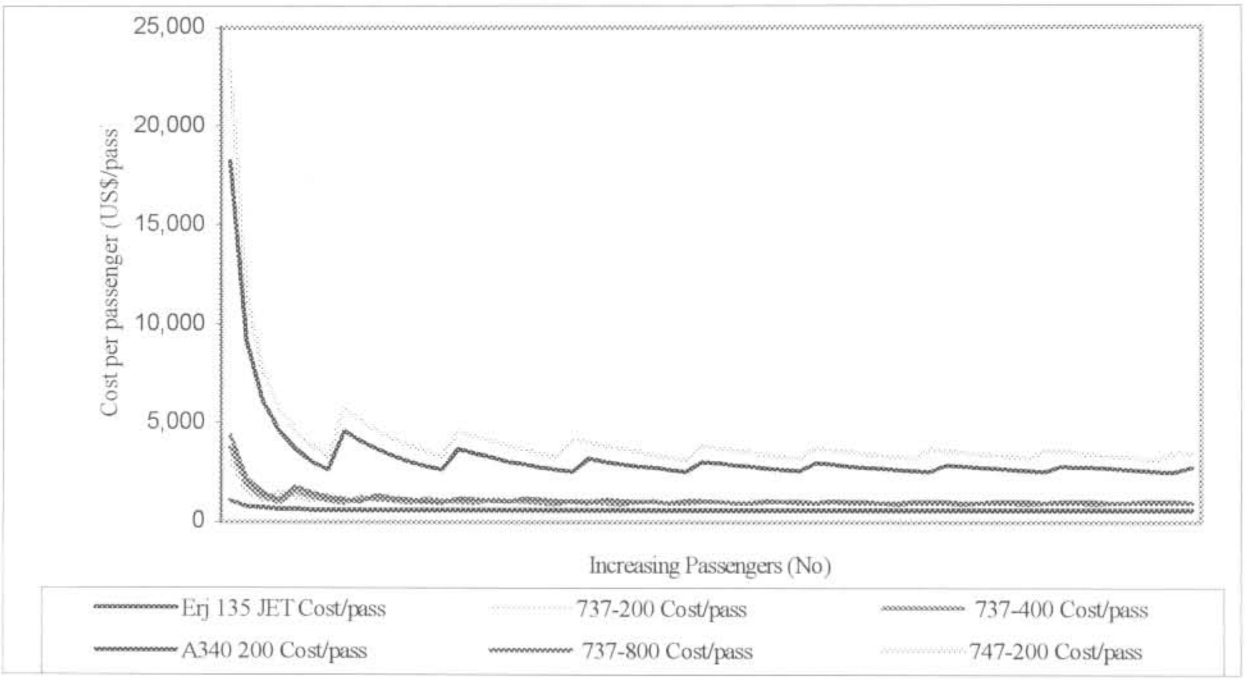

Figure 11: Operating costs per passenger for increasing passenger numbers

6 CHAPTER SIX: MODEL APPLICATION

6.1 Overview

In this chapter, the applications of the cost model to the Africa network will be given. This model can be used to build the conventional 3-step transport-planning model composed of trip generation, trip distribution and trip assignment to get existing passenger data. The model requires on ground input data for distances and passengers for each O – D pair and the model can calculate the costs of running a service along all these routes, for 11 different aircraft types.

Since the model is based on airports within the African continent, country specific data relevant to this study is needed. The 50 countries within the continent, will be used to generate the trips specific to air travel at the major international airports. From this a 50x50 origin- destination matrix will be formed.

6.2 Trip generation

Under this section, the number of passenger trips who are currently using air transport needs to be calculated. The lack of adequate data resources within most African countries, made it difficult to compile this data, so available data had to be manipulated for this study.

6.2.1 Passenger data

Gross domestic product is defined by the World Bank as a measure of total output of goods and services for final use produced by residents and non-residents, regardless of allocation to domestic and foreign claims. Hanlon (1999) suggests an elastic relationship between the GDP per capita of each country and the number air travel passengers as seen in the literature.

Taneja (1978), suggests that since GDP is a measure of the economic well-being of people within a nation, it can be assumed that the higher the GDP, the greater the output of goods and services, the richer people are, therefore the more they will travel for business and pleasure purposes.

This relationship can be analysed, to relate GDP/capita and number of air passengers. To relate this to the number of air passengers, the rate would need to be multiplied by the population i.e. trips/person = f (GDP/capita)

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World Bank data query is an online database that is used to find out data from different countries, spanning from 1997-2000 for various economic indicators. World Bank (2002) was used this for study. The database provides information for all African countries on population, GDP (US$) and aircraft departures/year. The aircraft departures for each country are shown in Appendix I.

6.2.2 Regression Analysis

Multiple Regression analysis was run on the aircraft departures, GDP or GDP per capita from each set of data, to create a multiple linear regression equation using the least squares technique, to confirm the relationship. Regressions were run using GDP, population and GDP/capita. Figure 12 shows the coefficients and the R^2 value for the regression equation for annual departures based on GDP.

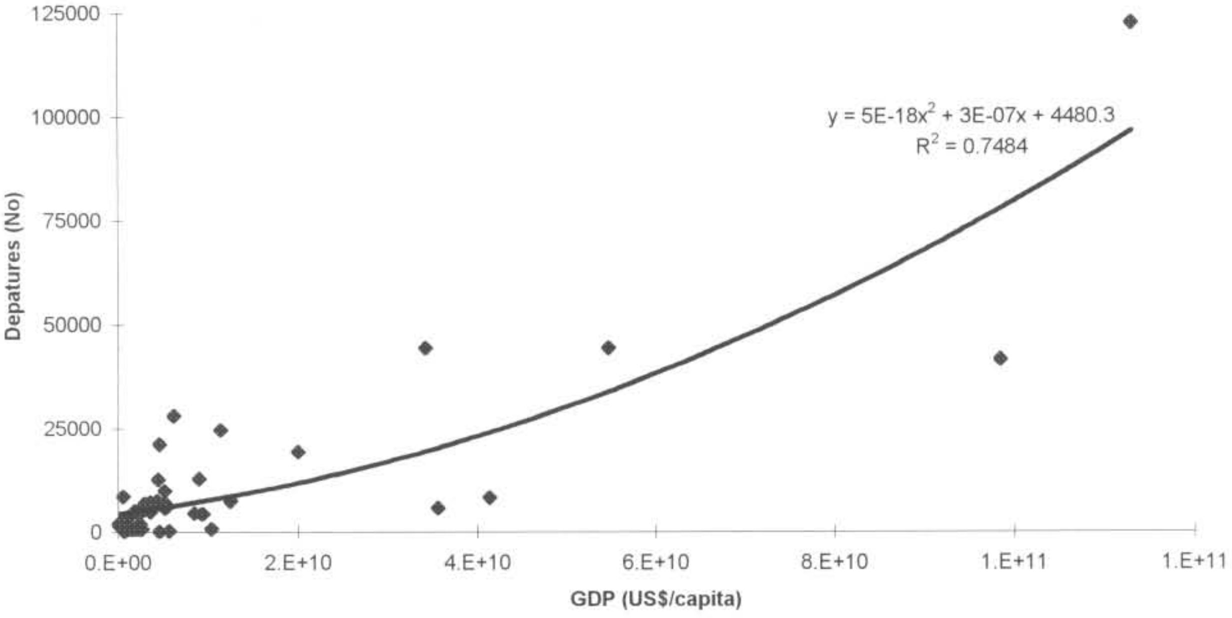

Figure 12: Graph showing GDP trend line with number aircraft departures

Linear regression analysis gives a correlation of 0.848, with an R^2 of 0,694 but it does not put into consideration exogenous factors like unemployment, route fare, tourism attractions, etc which in essence do affect the number of air travel passengers, and are all are function of GDP, but to an undefined exponential. That is why when the equation becomes a quadratic equation the R^2 increases and when a cubed power of GDP is used instead; the regression analysis gave an even better R^2 of 0,7484. This implies that there are many factors that are all functions of GDP, which result in the movement of people, from one country to another. The data has a few outliers, from countries like South Africa, Comoros, Ethiopia, etc, which countries have either booming tourism industry or act hubs for specific airlines.

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6.3 Trip Distribution

Airport identification and the distances between each of these airports were collected to define the routes. The International Air Transport Association (IATA) is an association that gathers information for approximately 280 airlines and about 95% of international scheduled air traffic. It uses a three-letter code for each airport, that it has been registered with the association.
In order to get the information needed for this study, a website called I Travel You Travel, gives a list of web-based utilities, meant to simplify the life of the traveler or website user. The utilities that will be used include:

6.3.1 List of airports

This gives a list of all airports and their three letter codes as given by IATA. For convenience the airports are listed under their respective countries in alphabetical order, for this study only one major international airport is recorded. Appendix A shows a list of all African countries, one major international airport per country and its respective three-letter code.

6.3.2 Airport distances

The one-way airport distances for all airports is calculated 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) as shown in Appendix B.

6.3.3 Total trips

To generate passenger trips moving within each of the countries within the African continent, to build the passenger data matrix, the following process was followed; According to AFRAA (2000) the total aircraft departures are multiplied by a factor of 15% to get the departures moving within Africa. Thereafter the trips generated between each O – D pair is calculated using the Furness method for a doubly constrained matrix. By trial and error method the values of β be 0,14, and α was calculated to be 52,02.

The cost matrix for each O-D is calculated using the distance matrix assuming an average speed of 800km/hr for all aircraft. Passengers calculated from the product average aircraft capacity of assumed to be 200 seats and the number of aircraft, for the respective O- D pair. Appendix C gives the above data and tables for the final trip distribution matrix.

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6.4 Cost comparisons

With all the input data for the distance and costs for a given route, a route network can be created for Africa. This means for a chosen aircraft fleet, application of the O-D pair specific passenger numbers and distances, the cost of running a given airline service can be computed, as well as other parameter values such as fleet size and frequency.

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 most economically efficient aircraft that can be used on this route according to the model. 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.

Table 29 Most efficient aircraft for EBB-JNB route

Parameters	Embraer Erj 135-JET	Boeing B737-200	Boeing B737-400	Airbus 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 Embraer Erj 135-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 Erj 135–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. 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 Erj 135-JET and the Boeing 737-200 aircraft are quite good.

6.5 Hubbing

From the comparison above and route analysis literature, the more passengers that are travelling for shorter routes, the cheaper it would be for airlines to run the service. The passenger matrix shows that the passenger demand is very low for example 3 passengers fly weekly from Uganda to Senegal. As a solution for the African continent, consolidating passenger traffic through hubbing could be a viable option to consider.

A hub is defined as an airport, which the airline would use as a terminus for routes: a point of concentrating arrivals and departures for passenger access to other flights. The proposal would be that for the African continent, four geographically located airport-hubs in the Northern, Southern Central and Eastern parts of Africa can be chosen and these alternative hubbing arrangements can be tested using the cost model

6.5.1 Justification

Kane (1996) writes that hubbing is a way in which airlines can save a lot of money, because hubbing reduces average sector lengths, and consolidates the number of passengers travelling over these short distances.

This implies therefore that a high proportion of its direct operating costs are incurred in take-off, landing, climb and descent. The effect of hubbing is shown in Table 30, giving the positive and negative effects on unit cost:

Table 30: Hubbing effects on cost of service

Positive	Negative
▪ Reduces the average sector distance flown ▪ Extra staff and handling equipment for shorter time intervals ▪ Intensive utilization of aircraft and crews, operating more flight hours per day.	▪ Additional Passenger Handling ▪ Places greater peak-load pressure on the hub airport

6.5.2 Hubbing models

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Examples of models dealing with different aspect of airline services, and employing different methodologies, have been used as a basis for analysing hubs; for example:

1. Traffic demand forecasting

Dennis (2002) developed a methodology for assessing the future route network and flight schedule at a medium-sized European airport. The starting point is the existing origin and destination demand from the base airport across the world. This is expanded using growth rates by country or region for the period up to year 2015. The future origin and destination demand is then converted into route traffic, subject to a threshold for direct service. Where demand falls below this level, traffic is reallocated via various appropriate hubs.

2. Passenger demand model

Hensher (2002) develops a method which involves the development and estimation of an econometric model capable of explaining the influences on passengers carried by airline j between points A and B over a regional network. Passengers traveling between points A and B include those in which their origin and destination are A and B and those who are flow-through passengers with A and B being either commencing or final points or both are intermediate on-line or inter-line connection points. An important attribute in the approach is an explicit treatment of current hubbing activity.

Hubbing has both positive and negative effects on passenger demand. On the negative side, there are time penalties as well as the disutility associated with making a connection rather than flying non-stop. On the other hand, hubbing can significantly reduce the passengers' schedule wait and add many origin–destination pairs to the network. Costs can be reduced due to higher traffic densities, but they are offset to varying degrees by the circuitous routings sometimes involved in hub operations.

6.5.3 Cost analysis of hubbing option

Hubbing can be analysed using the model and by following the process outlined below:

1. Creation of a suitable hubbing arrangement within the African continent, as shown in Figure 13. This implies that the choice in hub locations needs to be justified.
2. The specific links will be defined in the model, in as far as average sector distance, airfares, minimum frequencies, etc.

3. Calculation of operating costs of aircraft modes, for the given links will be calculated using

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the model,

4. Evaluation of each link, for economic analysis, choosing the least expensive link as the favorable option.
5. Repeat procedure for other hubbing arrangements, such that the least expensive hub and spoke network for Africa can be defined.

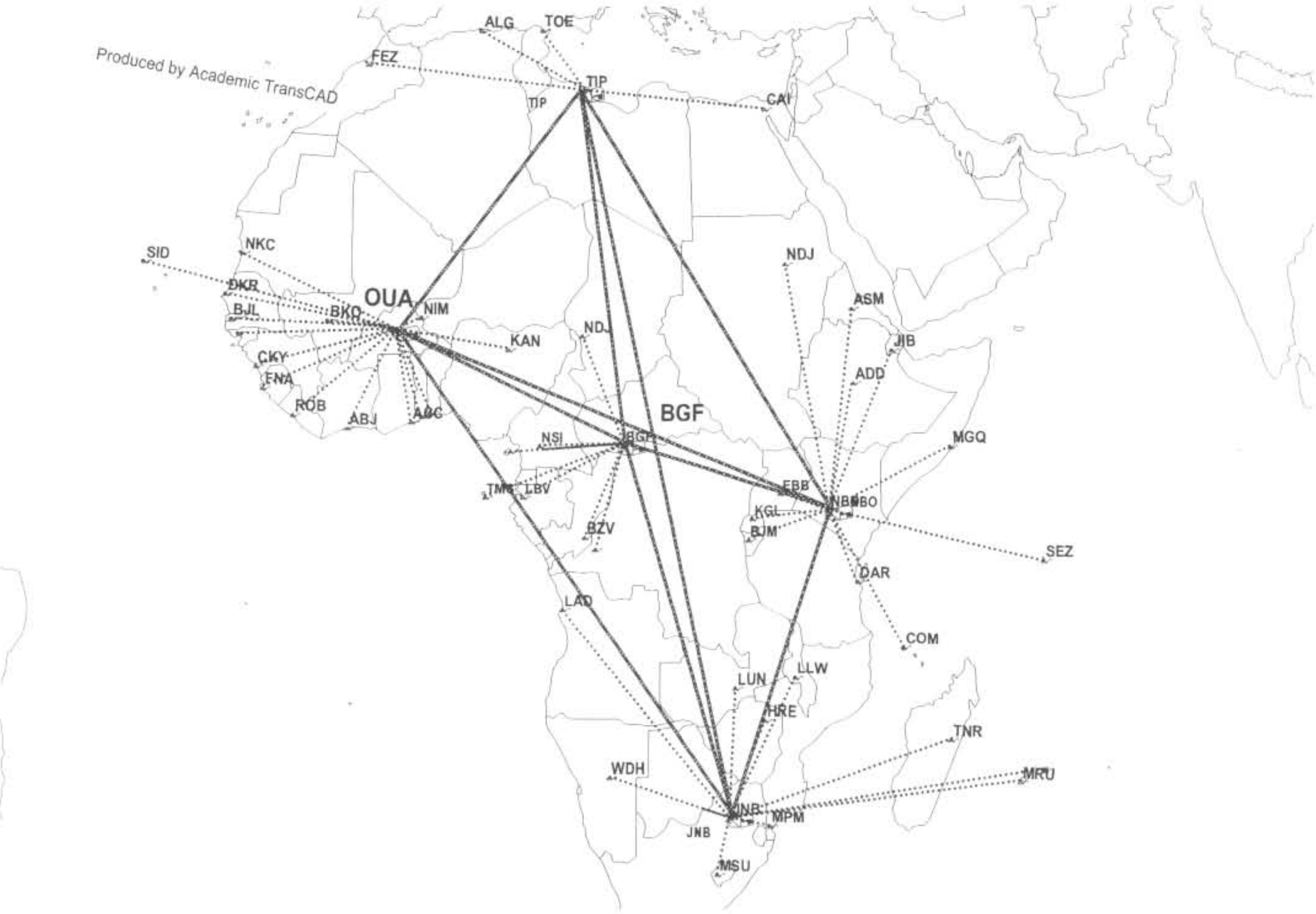

Figure 13: Proposed hub movements within the African continent

Due to time constraints the extent work involved in studying the hub network, could not be carried out but will be an interesting area for future research.

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7 CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATIONS

7.1 Introduction

The purpose for this study was to develop a model that would be able to estimate the cost of an airline service along a given route, given aircraft technical specifications and data relevant for different components of the cost structure. This information was then to be applied to the African region as a tool to design an economically efficient service along each route, within the continent.

7.1.1 Operating cost structure

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 i.e. revenues from investments like shares, real estate, profits from affiliated companies, interest from loans, etc.

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. The latter include all those costs that have to be incurred regardless of the type of aircraft; examples include general administration, marketing, sales and commission, etc.

For this study, the operating items, were considered and sub divided under the following headings: Standing Costs-, which included all costs that are incurred on the aircraft. These costs are as a result of acquiring the aircraft and are not dependent on whether the aircraft is being utilised or not. They include: depreciation, insurance and interest costs. The equations compiled for these components of costs were all calculated per hour utilised, implying that the more the aircraft is utilised, the faster these costs are paid off.

Flying costs include the costs that are incurred during the aircraft's flight time; they include fuel, crew costs and maintenance. These cost components are the running costs of the aircraft during flight time.

Other costs which costs include all other expenses incurred while running the airline service i.e. commission, passenger handling, while some stay constant and are incurred regardless of the passenger demand i.e. landing fees, parking fees, and general administrative costs.

7.1.2 Model structure

The model structure followed a systematic procedure combining the costs that are incurred for any given route, per hour utilised. This then enabled the output of this model to give different costs per aircraft type for the same trip. Using the route characteristics and the operating costs calculated, the output sheet then compiles a cost analysis for the service being provided including: cost per aircraft-km, cost per passenger at full capacity and existing passenger demand, costs per available seat-km, cost per hour utilised and utilisation coefficient. The model calculates the operating costs, from which the most economic aircraft type can be chosen to serve a route at a suitable design frequency and fleet size. Service performance and efficiency indicators calculated are also used as a measure for the aircraft type chosen, the higher the value the better the service.

7.1.3 Route cost analysis

All these component of the costs structure are analysed to assess the impact on the operating costs. The major determinants were found to include fuel, crew costs, frequency of flights (utilisation) and passenger demand. This implied that, the model had to have a variety of aircraft with different seat sizes to balance the load factors the point at which profits can be attained, with reasonable frequency of flights, whilst keeping operating costs at a minimum. On the other hand, aircraft types with varying technical characteristics like maximum range; maximum fuel capacity also had an effect of lowering operating costs.

Generally, smaller aircraft were found to have lower 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 flying 400-seater aircraft at lower flight frequency. This is the basic principle used by low-cost air carriers flying low capacity planes over short distances at high frequencies.

7.1.4 Route service operations

The model was applied to varying distances and passenger demand, to design an optimum service. For each distance, per aircraft type the maximum and minimum trips to meet demand were calculated and the appropriate fleet size chosen.

The biggest factors affecting fleet size are the number of hours utilised from the sector distance and frequency of flights, since the shorter the distance, the larger the aircraft trips one aircraft can make. In situations where the trips are longer, each aircraft has a maximum number of trips it can make,

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this implies that the fleet size has to increase if the demand is not met. Economies of scale on routes are achieved by monitoring the load factors and where possible extra utilisation of aircraft by leasing.

The hyperbolic relationship between costs per passenger and increasing passenger numbers was confirmed by the model, proving the theory that for long haul routes especially, the greater the passenger numbers, the lower the costs since the operating costs for this route are spread over more passengers. This explains why for busy routes in the aviation industry, airlines can charge low airfares, using larger more expensive aircraft, because costs are spread over more people.

7.1.5 Africa Application

Databases for Africa input data for route length and passenger data were created in two 50 X 50 matrices. By automatically linking these matrices to the model, all routes within Africa, will be analysed.

In order to summarise whether the problems have been addressed by this study, 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, and analysis of the route done. Suggestions about further research on the cost-effectiveness of moving limited passenger demand from their origin to destination by hubbing to consolidate passenger traffic, was done.

In conclusion, the cost model, developed can be used to address 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

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7.2 Recommendations

Based on the findings of this study, it is recommended that:

1. Based on the model, a sensitivity analysis should be carried out to determine the relative importance of the input data. This will define the date for which accurate and up-to-date information must be collected for successful application
2. 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.
3. Civil aviation authorities, airlines, and airport companies, create, compile and update databases for the air passenger traffic, to assist further research into the field.
4. 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, which are a big problem faced by the airline industry
5. Further study and research need to be done to the model, in its application of creating a hub and spoke network within Africa, as a way of consolidating passenger traffic to lower costs.

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APPENDICES

A. Demographic data

Appendix A gives the demographical details of all African countries that have been used in the study, these include country, capital city, and one international airport name and its code, County GDP and aircraft departures from each country.

	COUNTRY	CAPITAL	INTERNATIONAL AIRPORTS	CODE	GDP	DEPARTURES
1	Algeria	Algiers	Algiers	ALG	5.E+10	44 300
2	Angola	Luanda	Luanda	LAD	9.E+09	4 400
3	Benin	Porto Novo	Porto Novo (Cotonou)	COO	2.E+09	700
4	Botswana	Gaborone	Gaborone	GBE	5.E+09	7 100
5	Burkina Faso	Ouagadougou	Ouagadougou	OUA	2.E+09	2 000
6	Burundi	Bujumbura	Bujumbura	BJM	7.E+08	3 121
7	Cameroon	Yaounde	Nsimalen International	NSI	9.E+09	4 700
8	Cape Verde Islands	Prata	Amil Cabral Int'l Airport	SID	6.E+08	8 700
9	Central African Republic	Bangui	Bangui (M'poko)	BGF	1.E+09	700
10	Chad	N'Djameni	N'Djameni	NDJ	2.E+09	700
11	Comoros			COM	2.E+08	2 226
12	Congo Dem. Rep	Kinshasa	Kinshasa (Ndjili)	FIH	5.E+09	9 999
13	Congo. Rep.	Brazaville	Brazaville (Maya Maya)	BZV	3.E+09	5 200
14	Cote D'Ivoire	Abidjan	Abidjan (Port Bouet)	ABJ	1.E+10	700
15	Djibouti	Djibouti	Djibouti- Ambouli	JIB	6.E+08	2 909
16	Egypt	Cairo	Cairo	CAI	1.E+11	41 400
17	Equatorial Guinea		Malabo Airport	SSG	2.E+09	5 172
18	Eritrea	Asmara	Asmara (Yohannes IV)	ASM	7.E+08	3 119
19	Ethiopia	Addis Ababa	Addis Ababa	ADD	6.E+09	28 100
20	Gabon	Libreville	Libereville	LBV	4.E+09	7 500
21	Gambia, The	Banjul	Banjul	BJL	4.E+08	2 554
22	Ghana	Accra	Accra	ACC	5.E+09	5 900
23	Guinea	Conakry	Conakry-Gbeissa	CKY	3.E+09	6 978
24	Guinea Bissau	Bissau	Bissau - Osvaldo	BXO	2.E+08	2 183
25	Kenya	Nairobi	Nairobi	NBO	1.E+10	24 700
26	Lesotho	Maseru	Maseru- Moshoeshoe	MSU	8.E+08	3 322
27	Liberia	Monrovia	Roberts Int'l	ROB	5.E+08	2 808
28	Libya	Tripoli	Tripoli (Idris)	TIP	4.E+10	5 900
29	Madagascar	Antananarivo	Antananarivo (Ivato)	TNR	5.E+09	21 200
30	Malawi	Lilongwe	Lilongwe-Senou	LLW	2.E+09	4 700
31	Mali	Bamako	Bamako	BKO	3.E+09	700
32	Mauritania	Nouakchott	Nouakchott	NKC	1.E+09	2 200
33	Mauritius	Mauritius	Mauritius	MRU	5.E+09	12 800
34	Morocco	Rabat	Fes Saiss Int'l airport	FEZ	3.E+10	44 300
35	Mozambique	Maputo	Maputo	MPM	4.E+09	7 300
36	Namibia	Windhoek	Windhoek (Eros)	WDH	3.E+09	5 500
37	Niger	Niamey	Niamey	NIM	2.E+09	700
38	Nigeria	Abuja	Kanu - Mallam Amim	KAN	4.E+10	8 400
39	Rwanda	Kigali	Kigali	KGL	2.E+09	4 919
40	Senegal	Dakar	Dakar	DKR	5.E+09	200
41	Sierra Leone	Freetown	Freetown (Lungi Airport)	FNA	7.E+08	100
42	Somalia	Mogadishu	Mogadishu	MGQ	0.E+00	1 789
43	South Africa	Pretoria	Johannesburg	JNB	1.E+11	122 300
44	Sudan	Khartoum	Khartoum	KRT	1.E+10	7 600
45	Tanzania	Dar es salaam	Dar es salaam	DAR	9.E+09	4 500
46	Togo	Lome	Lome- Tokoin	LFW	1.E+09	700
47	Tunisia	Tunis	Tunis (Carthage Airport)	TOE	2.E+10	19 400
48	Uganda	Kampala	Entebbe	EBB	6.E+09	300
49	Zambia	Lusaka	Lusaka	LUN	4.E+09	4 900
50	Zimbabwe	Harare	Harare	HRE	9.E+09	13 000

B: 50 by 50 Distance matrix of the airports within Africa. ITYT (2003)

CODE	ABJ	ACC	ADD	ALG	ASM	BGF	BJL	BJR	BKO	BLZ	BXO	BZV	CAI	CKY	COO	DAR	DKR	EBB
ABJ	▨	419	3869	3497	3983	2658	1659	2979	880	4087	1484	1627	3993	1171	216	4123	1820	3202
ACC	419	▨	4278	4761	746	2084	2002	3389	1104	4456	1840	1986	4260	1548	239	4533	2151	3621
ADD	3869	4278	▨	4761	746	2285	2476	1692	3442	2710	2561	2985	2518	2769	4043	1366	2421	1197
ALG	3497	4761	4761	▨	4253	3910	2923	5210	2747	6667	3028	4710	2708	3193	3392	6091	2822	5061
ASM	3983	746	746	4253	▨	2531	2410	2325	3402	3448	2544	3398	1821	2820	4129	2428	2304	1850
BGF	2658	2084	2285	3910	2531	▨	3996	1473	2728	2634	3852	1022	3136	3588	1785	2611	4117	1614
BJL	1659	2002	2476	2923	2410	3996	▨	2322	932	3758	195	1953	2406	533	1767	3325	182	2272
BJM	2979	3389	1692	5210	2325	1473	2322	▨	3234	2994	2355	2997	2173	2593	3891	2003	2175	1378
BKO	880	1104	3442	2747	3402	2728	932	3234	▨	4286	881	2015	3155	728	897	4073	1107	3052
BLZ	4087	4456	2710	6667	3448	2634	3758	2994	4286	▨	3684	2470	5077	3616	4302	1104	3847	1735
BXO	1484	1840	2561	3028	2544	3852	195	2355	881	3684	▨	1785	2600	339	1603	3309	376	2262
BZV	1627	1986	2985	4710	3398	1022	1953	2997	2015	2470	1785	▨	4189	1538	1840	2671	2119	1961
CAI	3993	4260	2518	2708	1821	3136	2406	2173	3155	5077	2600	4189	▨	2938	10113	4162	2226	3351
CKY	1171	1548	2769	3193	2820	3588	533	2593	728	3616	339	1538	2938	▨	1309	3349	712	2324
COO	216	239	4043	3392	4129	1785	1767	3891	897	4302	1603	1840	10113	1309	▨	4335	1919	3407
DAR	4123	4533	1366	6091	2428	2611	3325	2003	4073	1104	3309	2671	4162	3349	4335	▨	3363	1054
DKR	1820	2151	2421	2822	2304	4117	182	2175	1107	3847	376	2119	2226	712	1919	3363	▨	2310
EBB	3202	3621	1197	5061	1850	1614	2272	1378	3052	1735	2262	1961	3351	2324	3407	1054	2310	▨
FEZ	3192	3192	4463	346	3983	4203	2578	4127	2420	6324	2682	4371	2521	2850	3098	5762	2478	4728
FIH	1645	2004	2976	4723	3393	1028	1961	2990	2029	2453	1794	17	4192	1549	1858	2655	2127	1949
FNA	1072	1463	2827	3307	2911	3548	674	2666	750	3550	480	1411	3080	146	1225	3328	855	2318
GBE	4085	4364	3944	7220	4653	3309	4335	4183	4562	1362	4206	2548	6112	4027	4280	2450	4469	2819
HRE	3946	4290	3070	6748	3795	2811	3825	3330	4245	466	3727	2319	5348	3615	4157	1539	3933	2002
JIB	4360	4763	560	4883	630	2805	2881	637	3868	3119	2990	3542	2415	3230	4525	2036	2800	1737
JNB	4370	4654	4029	7468	4752	3521	4569	4286	4830	1364	4446	2818	6270	4279	4567	2468	4697	2942
KAN	892	1144	3360	2792	3329	1396	918	3155	86	4207	800	1952	3120	641	928	3987	1040	2965
KGL	3006	3420	1488	5085	2114	1464	2226	1645	2930	1615	2190	1686	3531	2208	3214	1144	2287	301
KRT	3333	3708	1033	3730	682	1972	1733	691	2723	3456	1874	2918	1622	2163	3470	2565	1623	1733
LAD	1881	2167	3436	5177	3905	1585	2500	3484	2440	2432	2325	565	4754	2054	2075	2866	2670	2330
LBV	810	1169	3406	4100	3666	1113	1668	3334	1354	3288	1475	820	4067	1145	1021	3404	1850	2564
LFW	321	121	4164	3412	4248	1934	1881	4012	989	4394	1719	1927	4144	1428	121	4445	2030	3522
LLW	3407	3794	797	3964	578	2634	1854	463	2846	3249	1979	2868	1834	2246	3555	2337	1761	1541
LUN	3544	3893	2896	6367	3597	2435	3445	3126	3842	658	3341	1917	5068	3220	3756	1521	3559	1759
MGQ	4595	5014	1018	5779	1631	2987	3385	1326	4303	2261	3439	3412	3451	3593	4789	1165	3357	1454
MPM	4647	4954	3899	7616	4637	3680	4697	4181	5044	1189	4589	3054	6238	4452	4850	2267	4812	2887
MRU	6497	6885	3801	8514	4442	5079	5819	4154	6549	2475	5804	4914	6259	5831	6713	2495	5851	3547
MSU	4617	4878	4403	7789	5128	3884	4905	4662	5122	1724	4776	3107	6644	4596	4807	2826	5039	3319
NBO	3741	4159	1121	5478	1860	2122	2770	1412	3582	1589	2774	2444	3547	2855	3946	629	2791	540
NDJ	1440	1788	2631	2977	2605	944	221	2422	812	3746	73	1812	2618	323	1552	3379	394	2333
NIM	806	774	4033	2718	3987	2073	1581	3826	593	4721	1473	2328	3611	1292	675	4598	1685	3598
NKC	1904	2173	2724	2401	2507	4054	538	2448	1070	4267	686	2471	2091	966	1957	3765	420	2714
NSI	12004	12133	8611	9815	8211	985	10348	8591	11209	10466	10530	11586	8066	10860	12089	9505	10184	9736
OUA	826	747	4122	2730	4076	2382	1671	3915	682	4784	1562	2379	3686	1377	676	4676	1774	3679
ROB	720	1131	3148	3466	3276	3213	1048	3010	744	3595	856	1271	3451	517	900	3495	1226	2529
SID	2396	2734	1984	2923	1760	4735	737	1697	1685	3813	918	2463	1741	1251	2501	3168	584	2145
SSG	538	947	3410	3739	3593	1089	1426	3299	993	3564	1233	1127	3830	894	752	3587	1605	2680
TIP	9814	9471	12343	7587	11780	3201	10274	11998	9610	13879	10303	11441	10022	10308	9602	13597	10234	12543
TMS	625	931	3672	4056	3908	1384	1810	3589	1331	3532	1616	1063	4216	1278	818	3680	1990	2844
TNR	5439	5821	3152	7687	3867	4085	4881	3498	5545	1394	4845	3843	5669	4839	5655	1596	4934	2632
TUN	3220	3259	4221	540	3720	3697	2450	3880	2407	6166	2571	4302	2233	2768	3144	5563	2334	4539
WDH	3317	3515	4367	6712	4988	2989	4013	4524	3968	2253	3847	2062	6144	3591	3484	3186	4177	3170

B: 50 by 50 Distance matrix of the airports within Africa. ITYT (2003)

CODE	FEZ	FIH	FNA	GBE	HRE	JIB	JNB	KAN	KGL	KRT	LAD	LBV	LFW	LLW	LUN	MGQ	MPM	MRU
ABJ	3192	1645	1072	4085	3946	4360	4370	892	3006	3333	1881	810	321	3407	3544	4595	4647	6497
ACC	3192	2004	1463	4364	4290	4763	4654	1144	3420	3708	2167	1169	121	3794	3893	5014	4954	6885
ADD	4463	2976	2827	3944	3070	560	4029	3360	1488	1033	3436	3406	4164	797	2896	1018	3899	3801
ALG	346	4723	3307	7220	6748	4883	7468	2792	5085	3730	5177	4100	3412	3964	6367	5779	7616	8514
ASM	3983	3393	2911	4653	3795	630	4752	3329	2114	682	3905	3666	4248	578	3597	1631	4637	4442
BGF	4203	1028	3548	3309	2811	2805	3521	1396	1464	1972	1585	1113	1934	2634	2435	2987	3680	5079
BJL	2578	1961	674	4335	3825	2881	4569	918	2226	1733	2500	1668	1881	1854	3445	3385	4697	5819
BJM	4127	2990	2666	4183	3330	637	4286	3155	1645	691	3484	3334	4012	463	3126	1326	4181	4154
BKO	2420	2029	750	4562	4245	3868	4830	86	2930	2723	2440	1354	989	2846	3842	4303	5044	6549
BLZ	6324	2453	3550	1362	466	3119	1364	4207	1615	3456	2432	3288	4394	3249	658	2261	1189	2475
BXO	2682	1794	480	4206	3727	2990	4446	800	2190	1874	2325	1475	1719	1979	3341	3439	4589	5804
BZV	4371	17	1411	2548	2319	3542	2818	1952	1686	2918	565	820	1927	2868	1917	3412	3054	4914
CAI	2521	4192	3080	6112	5348	2415	6270	3120	3531	1622	4754	4067	4144	1834	5068	3451	6238	6259
CKY	2850	1549	146	4027	3615	3230	4279	641	2208	2163	2054	1145	1428	2246	3220	3593	4452	5831
COO	3098	1858	1225	4280	4157	4525	4567	928	3214	3470	2075	1021	121	3555	3756	4789	4850	6713
DAR	5762	2655	3328	2450	1539	2036	2468	3987	1144	2565	2866	3404	4445	2337	1521	1165	2267	2495
DKR	2478	2127	855	4469	3933	2800	4697	1040	2287	1623	2670	1850	2030	1761	3559	3357	4812	5851
EBB	4728	1949	2318	2819	2002	1737	2942	2965	301	1733	2330	2564	3522	1541	1759	1454	2887	3547
FEZ	▨	4383	2965	6876	6403	4610	7123	2462	4746	3436	4843	3773	3125	3668	6021	5481	7271	8197
FIH	4383	▨	1423	2533	2302	3534	2803	1966	1673	2915	563	837	1944	2864	1900	3399	3038	4897
FNA	2965	1423	▨	3918	3532	3301	4174	666	2184	2263	1918	999	1345	2335	3133	3622	4358	5800
GBE	6876	2533	3918	▨	912	4408	293	4497	2595	4525	2204	3296	4340	4351	1059	3614	686	3268
HRE	6403	2302	3532	912	▨	3513	959	4170	1823	3734	2179	3136	4239	448	404	2703	901	2775
JIB	4610	3534	3301	4408	3513	▨	4469	3790	2034	1232	3996	3939	4646	1046	3378	1064	4300	3849
JNB	7123	2803	4174	293	959	4469	▨	4764	2739	4667	2492	3578	4628	4483	1202	3622	432	3046
KAN	2462	1966	666	4497	4170	3790	4764	▨	2845	2651	2388	1312	1026	2770	3768	4218	4973	6464
KGL	4746	1673	2184	2595	1823	2034	2739	2845	▨	1930	2035	2329	3327	1758	1541	1727	2721	3624
KRT	3436	2915	2263	4525	3734	1232	4667	2651	1930	▨	3457	309	3588	239	3471	2050	4619	4825
LAD	4843	563	1918	2204	2179	3996	2492	2388	2035	3457	▨	1109	2137	3392	1805	3745	2788	4907
LBV	3773	837	999	3296	3136	3939	3578	1312	2329	309	1109	▨	1107	3095	2735	4005	3843	5719
LFW	3125	1944	1345	4340	4239	4646	4628	1026	3327	3588	2137	1107	▨	3675	3840	4908	4919	6813
LLW	3668	2864	2335	4351	448	1046	4483	2770	1758	239	3392	3095	3675	▨	3293	1815	4421	4586
LUN	6021	1900	3133	1059	404	3378	1202	3768	1541	3471	1805	2735	3840	3293	▨	2668	1253	3112
MGQ	5481	3399	3622	3614	2703	1064	3622	4218	1727	2050	3745	4005	4908	1815	2668	▨	3391	2813
MPM	7271	3038	4358	686	901	4300	432	4973	2721	4619	2788	3843	4919	4421	1253	3391	▨	2615
MRU	8197	4897	5800	3268	2775	3849	3046	6464	3624	4825	4907	5719	6813	4586	3112	2813	2615	▨
MSU	7445	3092	4486	571	1333	4837	377	5059	3115	5043	2736	3839	4861	4860	1576	3974	633	3173
NBO	5152	2430	2854	2845	1956	1564	3914	3496	763	1941	2756	3088	4061	1716	1817	990	2778	3065
NDJ	2632	1822	469	4251	3783	3057	4493	733	2258	1932	2346	1468	1667	2041	3396	3511	4641	5874
NIM	2427	2344	1281	4847	4631	4460	5127	673	3455	3307	2656	1551	698	3435	4227	4884	5381	7051
NKC	2057	2480	1110	4872	4351	3052	5105	1030	2703	1831	3007	2097	2056	2006	3975	3694	5228	6247
NSI	9893	11578	10983	11771	10931	8051	11655	11166	10037	8777	12046	11855	12192	8770	11016	8415	11272	8855
OUA	2446	2396	1363	4889	4688	4549	5170	762	3533	3396	2692	1593	683	3524	4284	4970	5430	7125
ROB	3133	1286	385	3819	3525	3641	4087	683	2357	2637	1710	676	1020	2698	3121	3892	4308	5929
SID	2596	2467	1383	4609	3971	2297	4811	1621	2201	1080	3028	2342	2613	1252	3628	2973	4870	5609
SSG	3413	1144	756	3645	3442	3922	3923	955	2474	2971	1470	364	858	3016	3039	4090	4177	5962
TIP	7896	11459	10357	13742	13758	12405	14035	9692	12492	11311	11617	10623	9520	11547	13358	13359	14388	16080
TMS	3738	1081	1137	3462	3359	4200	3749	1307	2610	3306	1258	280	886	3334	2962	4284	4034	5976
TNR	7356	3825	4795	2311	1712	3349	2134	5461	2656	4119	3826	4653	5752	3883	2035	2290	1727	1080
TUN	289	4314	2891	6776	6266	4349	7016	2439	4573	3190	4794	3749	3182	3424	5892	5239	7145	7976
WDH	6381	2053	3458	1176	1803	4898	1439	3920	2884	4687	1543	2617	3518	4566	1672	4310	1860	4430

B: 50 by 50 Distance matrix of the airports within Africa. ITYT (2003)

CODE	MSU	NBO	NDJ	NIM	NKC	NSI	OUA	ROB	SID	SSG	TIP	TMS	TNR	TOE	WDH
ABJ	4617	3741	1440	806	1904		826	720	2396	538	9814	625	5439	3220	3317
ACC	4878	4159	1788	774	2173	12133	747	1131	2734	947	9471	931	5821	3259	3515
ADD	4403	1121	2631	4033	2724	8611	4122	3148	1984	3410	12343	3672	3152	4221	4367
ALG	7789	5478	2977	2718	2401	9815	2730	3466	2923	3739	7587	4056	7687	540	6712
ASM	5128	1860	2605	3987	2507	8211	4076	3276	1760	3593	11780	3908	3867	3720	4988
BGF	3884	2122	944	2073	4054	985	2382	3213	4735	1089	3201	1384	4085	3697	2989
BJL	4905	2770	221	1581	538	10348	1671	1048	737	1426	10274	1810	4881	2450	4013
BJM	4662	1412	2422	3826	2448	8591	3915	3010	1697	3299	11998	3589	3498	3880	4524
BKO	5122	3582	812	593	1070	11209	682	744	1685	993	9610	1331	5545	2407	3968
BLZ	1724	1589	3746	4721	4267	10466	4784	3595	3813	3564	13879	3532	1394	6166	2253
BXO	4776	2774	73	1473	686	10530	1562	856	918	1233	10303	1616	4845	2571	3847
BZV	3107	2444	1812	2328	2471	11586	2379	1271	2463	1127	11441	1063	3843	4302	2062
CAI	6644	3547	2618	3611	2091	8066	3686	3451	1741	3830	10022	4216	5669	2233	6144
CKY	4596	2855	323	1292	966	10860	1377	517	1251	894	10308	1278	4839	2768	3591
COO	4807	3946	1552	675	1957	12089	676	900	2501	752	9602	818	5655	3144	3484
DAR	2826	629	3379	4598	3765	9505	4676	3495	3168	3587	13597	3680	1596	5563	3186
DKR	5039	2791	394	1685	420	10184	1774	1226	584	1605	10234	1990	4934	2334	4177
EBB	3319	540	2333	3598	2714	9736	3679	2529	2145	2680	12543	2844	2632	4539	3170
FEZ	7445	5152	2632	2427	2057	9893	2446	3133	2596	3413	7896	3738	7356	289	6381
FIH	3092	2430	1822	2344	2480	11578	2396	1286	2467	1144	11459	1081	3825	4314	2053
FNA	4486	2854	469	1281	1110	10983	1363	385	1383	756	10357	1137	4795	2891	3458
GBE	571	2845	4251	4847	4872	11771	4889	3819	4609	3645	13742	3462	2311	6776	1176
HRE	1333	1956	3783	4631	4351	10931	4688	3525	3971	3442	13758	3359	1712	6266	1803
JIB	4837	1564	3057	4460	3052	8051	4549	3641	2297	3922	12405	4200	3349	4349	4703
JNB	377	3914	4493	5127	5105	11655	5170	4087	4811	3923	14035	3749	2134	7016	1439
KAN	5059	3496	733	673	1030	11166	762	683	1621	955	9692	1307	5461	2439	3920
KGL	3115	763	2258	3455	2703	10037	3533	2357	2201	2474	12492	2610	2656	4573	2884
KRT	5043	1941	1932	3307	1831	8777	3396	2637	1080	2971	11311	3306	4119	3190	4687
LAD	2736	2756	2346	2656	3007	12046	2692	1710	3028	1470	11617	1258	3826	4794	1543
LBV	3839	3088	1468	1551	2097	11855	1593	676	2342	364	10623	280	4653	3749	2617
LFW	4861	4061	1667	698	2056	12192	683	1020	2613	858	9520	886	5752	3182	3518
LLW	4860	1716	2041	3435	2006	8770	3524	2698	1252	3016	11547	3334	3883	3424	4566
LUN	1576	1817	3396	4227	3975	11016	4284	3121	3628	3039	13358	2962	2035	5892	1672
MGQ	3974	990	3511	4884	3694	8415	4970	3892	2973	4090	13359	4284	2290	5239	4310
MPM	633	2778	4641	5381	5228	11272	5430	4308	4870	4177	14388	4034	1727	7145	1860
MRU	3173	3065	5874	7051	6247	8855	7125	5929	5609	5962	16080	5976	1080	7976	4430
MSU	▨	3287	4821	5390	5443	11898	5428	4378	5170	4192	14169	3992	2345	7347	1501
NBO	3287	▨	2846	4134	3182	9384	4216	3069	2557	3216	13015	3368	2218	4947	3390
NDJ	4821	2846	▨	1405	661	10569	1494	833	957	1212	10234	1598	4912	2526	3874
NIM	5390	4134	1405	▨	1580	11675	89	1129	2254	1205	9158	1419	6024	2485	4120
NKC	5443	3182	661	1580	▨	10139	1664	1431	754	1804	9835	2192	5343	1917	4533
NSI	11898	9384	10569	11675	10139	▨	11748	11368	9613	11726	11389	12077	9554	9670	12688
OUA	5428	4216	1494	89	1664	11748	▨	1198	2341	1253	9095	1446	6094	2514	4143
ROB	4378	3069	833	1129	1431	11368	1198	▨	1767	379	10285	767	4896	3092	3249
SID	5170	2557	957	2254	754	9613	2341	1767	▨	2138	10475	2514	4764	2396	4470
SSG	4192	3216	1212	1205	1804	11726	1253	379	2138	▨	10325	389	4907	3395	2981
TIP	14169	13015	10234	9158	9835	11389	9095	10285	10475	10325	▨	10402	15145	8127	12670
TMS	3992	3368	1598	1419	2192	12077	1446	767	2514	389	10402	▨	4906	3737	2703
TNR	2345	2218	4912	6024	5343	9554	6094	4896	4764	4907	15145	4906	▨	7159	3434
TUN	7347	4947	2526	2485	1917	9670	2514	3092	2396	3395	8127	3737	7159	▨	6337
WDH	1501	3390	3874	4120	4533	12688	4143	3249	4470	2981	12670	2703	3434	6337	▨

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	ABJ	ACC	ADD	ALG	ASM	BGF	BJL	BJM	BKO	BLZ	BXO	BZV	CAI	CKY	COO	DAR	DKR	EBB
ABJ	0	3870	9940	21470	1050	260	1210	1240	390	630	2530	20380	2610	1130	460	1340	100	110
ACC	3760	0	83340	155120	16660	2560	10200	10390	3370	5260	21400	172490	22410	9540	4080	11220	780	860
ADD	9660	83340	0	729710	78350	11630	44170	65730	10530	33540	88730	681270	143000	36230	9840	91860	3500	6140
ALG	20870	155100	729660	0	85900	17720	82710	71920	24070	33990	165610	1020260	280140	68130	22340	81380	6600	6320
ASM	1020	16660	78340	85900	0	1200	4820	6340	1150	3180	9590	68260	17400	3870	1050	8220	390	590
BGF	250	2560	11620	17720	1200	0	710	1430	250	720	1490	20090	2690	660	310	1550	60	120
BJL	1170	10200	44160	82720	4820	710	0	4840	1350	2300	11040	67070	11990	4410	1210	5360	430	420
BJM	1210	10390	65730	71930	6340	1430	4840	0	1170	3410	9810	72490	16200	3990	1080	8770	390	640
BKO	380	3370	10530	24080	1150	250	1350	1170	0	600	2770	18730	2970	1210	400	1330	110	110
BLZ	610	5260	33550	34000	3180	720	2300	3410	600	0	4750	48480	5950	2040	620	6260	180	370
BXO	2460	21400	88730	165620	9590	1490	11040	9810	2770	4740	0	140850	23630	9290	2530	10960	840	860
BZV	19810	172500	681340	1020430	68270	20100	67080	72500	18730	48480	140870	0	147940	62290	20060	101330	5110	7440
CAI	2540	22410	142990	280130	17400	2690	11990	16200	2970	5950	23630	147910	0	9430	920	15100	970	1130
CKY	1100	9540	36230	68130	3870	660	4410	3990	1210	2040	9290	62280	9430	0	1130	4610	340	360
COO	450	4070	9850	22340	1050	310	1210	1080	400	620	2530	20060	920	1130	0	1320	100	110
DAR	1300	11220	91870	81390	8220	1550	5360	8770	1330	6260	10960	101320	15100	4610	1320	0	420	890
DKR	90	780	3500	6600	390	60	430	390	110	180	840	5110	970	340	100	420	0	40
EBB	100	860	6140	6320	590	120	420	640	110	370	860	7440	1130	360	110	890	40	0
FEZ	20810	193010	726930	3026320	85160	15920	83090	82200	24110	34130	166380	1023770	273720	68410	22240	81520	6630	6330
FIH	4370	38060	151030	225320	15130	4450	14830	16070	4140	10770	31130	351280	32730	13760	4430	22490	1130	1650
FNA	50	440	1600	2980	170	30	200	180	60	100	410	2840	410	190	60	210	20	20
GBE	1930	17000	86070	98260	8190	2020	6610	8810	1800	8800	13780	152290	15790	6020	1960	15740	510	960
HRE	3680	32090	186860	198840	17730	4090	13460	19040	3530	19170	27920	295320	33620	12060	3730	34390	1040	2060
JIB	910	7790	76430	72650	8140	1080	4190	8040	1000	3180	8380	62860	14810	3400	920	8310	340	570
JNB	60930	537690	2821900	3131100	267810	64510	210990	287650	56880	292510	439640	4833880	511030	191680	61870	521990	16160	31140
KAN	4600	40750	130070	290970	14090	3840	16390	14380	5350	7300	34120	230620	36360	14860	4800	16410	1260	1280
KGL	1680	14470	95410	102980	9210	2010	6900	9900	1720	6070	14150	127720	17890	5970	1700	14270	540	1080
KRT	2710	23510	176580	223090	20230	3140	12840	19990	3050	7520	25550	175950	42700	10290	2780	19010	1030	1430
LAD	1870	16420	61840	92360	6140	1790	5990	6540	1710	4800	12590	141630	13170	5590	1900	9620	460	690
LBV	3960	34420	109460	196340	11270	3420	12200	11820	3640	7270	25720	238500	26140	11540	4010	15420	930	1160
LFW	440	4180	9680	22350	1030	300	1190	1060	400	610	2490	19830	2610	1110	480	1300	100	100
LLW	1620	14020	111430	129660	12470	1690	7620	12600	1810	4720	15190	107480	24920	6140	1660	11980	610	900
LUN	1470	12790	71610	79010	6830	1630	5350	7340	1410	6890	11110	117780	13130	4810	1490	12830	420	800
MGQ	520	4460	42170	37130	4080	630	2300	4270	560	2210	4630	38440	7390	1910	530	5790	190	360
MPM	1850	16200	91620	96830	8680	2000	6550	9300	1740	9580	13610	147200	16310	5910	1870	17160	510	1000
MRU	3160	27380	220950	196170	21280	3700	12760	22150	3170	18120	26080	252010	38530	11000	3200	39090	1000	2110
MSU	860	7550	38600	43230	3670	890	2910	3940	790	4020	6060	67110	6990	2650	870	7160	230	430
NBO	8540	73560	588840	556390	55730	10340	36260	59670	8880	35280	73900	647390	103240	30850	8660	90340	2830	5950
NDJ	330	2880	11690	22290	1270	330	1470	1300	380	630	3070	18700	3150	1250	350	1450	120	120
NIM	410	3740	9930	25320	1080	300	1260	1100	430	580	2610	18550	2870	1140	440	1270	100	100
NKC	990	8760	37420	80200	4190	630	4510	4190	1160	1860	8960	54210	11210	3620	1040	4390	370	350
NSI	6530	11210	97660	160220	11290	7760	5930	10450	1440	4590	11700	80410	28800	4680	1280	11760	480	740
OUA	1160	10850	28260	73030	3070	810	3570	3130	1200	1640	7420	53130	8180	3250	1250	3620	280	280
ROB	1510	13020	43010	82390	4530	890	5110	4700	1520	2590	10770	82780	10940	4840	1540	5700	390	440
SID	3620	31620	169620	291500	19000	2200	17340	19020	4150	8010	34260	216170	47450	13690	3740	19410	1400	1510
SSG	2900	25040	76530	146340	7990	2410	8900	8320	2710	4850	18780	158150	19060	8440	2940	10450	680	800
TIP	2620	25810	73440	341890	8730	7610	8670	8320	2750	3650	17590	119170	29550	7450	2860	8300	690	650
TMS	2980	26180	76240	144380	7880	2380	8680	8250	2670	5080	18310	166790	18580	8230	3030	10720	660	810
TNR	5550	48090	360880	330540	34300	6420	21920	36220	5510	31920	44980	443160	62280	19070	5610	66700	1710	3610
TUN	8030	73980	294080	1134360	34580	6750	32950	33290	9370	13610	65790	401820	111630	26920	8560	32740	2640	2540
WDH	1870	16760	67900	91230	6560	1810	5940	7050	1690	6400	12470	140840	13340	5520	1910	11760	460	770

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	FEZ	FIH	FNA	GBE	HRE	JIB	JNB	KAN	KGL	KRT	LAD	LBV	LFW	LLW	LUN	MGQ	MPM	MRU
ABJ	21420	4500	60	1980	3780	930	62720	4730	1730	2790	1920	4070	450	1670	1510	540	1900	3260
ACC	193030	38060	440	17000	32080	7790	537950	40750	14470	23510	16420	34420	4180	14020	12790	4460	16190	27380
ADD	726980	151020	1600	86050	186830	76430	2823180	130070	95410	176590	61840	109450	9680	111430	71600	42170	91600	220930
ALG	3026310	225290	2980	98240	198790	72650	3132310	290960	102970	223090	92340	196330	22350	129660	78990	37130	96800	196130
ASM	85160	15120	170	8190	17730	8140	267910	14090	9210	20230	6140	11270	1030	12470	6830	4080	8670	21270
BGF	15920	4450	30	2020	4090	1080	64530	3840	2010	3140	1790	3420	300	1690	1630	630	2000	3700
BJL	83090	14830	200	6610	13460	4190	211080	16390	6890	12840	5990	12200	1190	7620	5350	2300	6550	12760
BJM	82210	16070	180	8800	19040	8040	287770	14380	9900	19990	6540	11820	1060	12600	7340	4270	9300	22150
BKO	24110	4140	60	1800	3530	1000	56910	5350	1720	3050	1710	3640	400	1810	1410	560	1740	3170
BLZ	34140	10770	100	8800	19170	3180	292670	7300	6070	7520	4800	7270	610	4720	6890	2210	9580	18120
BXO	166390	31130	410	13780	27910	8380	439830	34120	14140	25550	12590	25720	2490	15190	11100	4630	13610	26080
BZV	1023940	351300	2840	152270	295310	62860	4836580	230640	127730	175980	141640	238520	19830	107490	117770	38450	147190	252010
CAI	273720	32720	410	15790	33620	14810	511220	36360	17890	42700	13160	26140	2610	24910	13130	7390	16310	38520
CKY	68420	13760	190	6020	12060	3400	191770	14860	5970	10290	5590	11540	1110	6140	4810	1910	5910	10990
COO	22240	4430	60	1960	3730	920	61900	4800	1700	2780	1890	4010	480	1660	1490	530	1870	3200
DAR	81530	22490	210	15740	34380	8310	522250	16410	14270	19020	9620	15420	1300	11980	12820	5790	17160	39090
DKR	6630	1130	20	510	1040	340	16170	1260	540	1030	460	930	100	610	420	190	510	1000
EBB	6340	1650	20	960	2060	570	31150	1280	1080	1430	690	1160	100	900	800	360	1000	2110
FEZ	0	226110	2990	98660	199680	72060	3146390	291500	103320	222100	92580	196590	22220	129130	79360	36990	97240	196050
FIH	226130	0	630	33790	65550	13940	1073180	50920	28340	38970	31360	52630	4380	23810	26150	8530	32670	55940
FNA	2990	630	0	280	550	150	8710	660	270	460	260	530	60	270	220	90	270	500
GBE	98690	33800	280	0	56440	8080	1124080	22080	16280	19850	15890	23110	1950	12390	20450	5550	33280	50220
HRE	199730	65560	550	56440	0	17590	1863880	43550	34720	42470	29730	44270	3690	45700	42720	12120	59720	102000
JIB	72060	13930	150	8070	17590	0	265850	12270	8820	17350	5710	10140	910	10850	6700	4260	8690	22290
JNB	3145160	1072640	8700	1123330	1862740	265740	0	701040	528170	644230	502620	731870	61450	402850	663600	184240	1157860	1737460
KAN	291510	50920	660	22070	43540	12270	701350	0	21260	37590	20990	44610	4740	22290	17370	6810	21450	39170
KGL	103330	28340	270	16280	34710	8820	528430	21260	0	22550	11810	19740	1680	14070	13560	5570	16820	34040
KRT	222100	38970	460	19850	42460	17350	644500	37590	22540	0	15730	48040	2740	31360	16530	8990	20620	47140
LAD	92590	31360	260	15890	29730	5710	502880	20990	11810	15730	0	22270	1880	9640	11800	3570	15150	24780
LBV	196610	52630	530	23100	44270	10150	732220	44620	19740	48040	22270	0	3960	17870	17650	6000	22170	37860
LFW	22220	4380	60	1950	3690	910	61480	4740	1680	2740	1880	3960	0	1630	1470	520	1860	3160
LLW	129130	23810	270	12390	45690	10850	403010	22290	14070	31360	9640	17870	1630	0	10330	5670	12930	29770
LUN	79380	26150	220	20450	42720	6700	663980	17370	13560	16530	11800	17660	1470	10330	0	4540	20880	35750
MGQ	36990	8530	90	5550	12120	4260	184320	6810	5570	8990	3570	6000	520	5670	4530	0	6090	15970
MPM	97270	32670	270	33280	59720	8690	1158630	21450	16820	20620	15150	22180	1860	12930	20880	6090	0	59460
MRU	196080	55940	500	50220	101990	22290	1738410	39170	34040	47150	24790	37860	3160	29770	35740	15970	59460	0
MSU	43420	14900	130	15630	25480	3640	538300	9730	7230	8810	7040	10220	870	5510	9080	2530	16330	24820
NBO	557040	143630	1380	90160	196260	55430	2490040	109790	93630	130220	60210	100030	8520	82020	74750	36640	96340	217230
NDJ	22390	4140	60	1830	3690	1110	58180	4610	1870	3380	1680	3440	340	2010	1470	610	1800	3440
NIM	25190	4100	60	1790	3450	940	56520	5050	1650	2880	1720	3680	440	1710	1380	530	1720	3040
NKC	80550	11980	160	5320	10860	3600	170060	14220	5610	11170	4850	10010	1020	6560	4320	1920	5280	10480
NSI	149460	17830	210	11630	25100	10960	395210	17650	11370	24220	7290	13270	1270	14680	9200	6150	13410	48510
OUA	72580	11730	150	5120	9880	2670	162180	14380	4680	8200	4940	10550	1250	4850	3940	1490	4920	8670
ROB	82590	18280	230	7920	15530	4020	251560	18710	7380	12010	7530	15890	1510	7200	6200	2300	7680	13710
SID	291890	47810	600	22190	46220	16340	713020	51070	24390	50720	19240	38190	3680	29800	18250	8680	22390	46630
SSG	146510	34900	390	15210	29360	7120	482300	33230	13470	21100	14630	31260	2900	12680	11710	4140	14640	25390
TIP	306280	26300	330	11910	22120	7390	376520	33000	10690	22460	11350	23790	2920	13050	8820	3740	11230	19800
TMS	144340	36800	380	16380	31070	7070	518540	32580	13720	20750	15840	33080	3010	12510	12380	4170	15650	26410
TNR	331210	98390	860	86560	179100	35460	2973130	68070	58790	77780	43660	66520	5540	49090	62920	25520	101260	268850
TUN	1120860	88750	1180	38940	79310	29250	1243150	113490	41300	89920	36210	76560	8530	52260	31480	14970	38550	79030
WDH	91420	31220	260	24570	41020	6520	781330	20750	13150	16390	15150	22110	1910	10140	15610	4170	23020	34810

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	MSU	NBO	NDJ	NIM	NKC	NSI	OUA	ROB	SID	SSG	TIP	TMS	TNR	TUN	WDH
ABJ	880	8780	340	420	1020	0	1190	1560	3730	2990	2700	3070	5710	8270	1930
ACC	7550	73560	2880	3740	8760	11260	10850	13020	31630	25040	25810	26180	48080	73980	16750
ADD	38590	588850	11690	9930	37420	98070	28260	43010	169630	76530	73450	76240	360830	294110	67890
ALG	43220	556370	22290	25310	80200	160890	73020	82390	291490	146320	341910	144360	330470	1134370	91210
ASM	3670	55730	1270	1080	4190	11330	3070	4530	19000	7990	8730	7880	34290	34580	6560
BGF	890	10340	330	300	630	7790	810	890	2200	2410	7610	2380	6410	6750	1810
BJL	2910	36260	1470	1260	4510	5950	3570	5110	17340	8900	8670	8680	21910	32950	5940
BJM	3940	59670	1300	1100	4190	10500	3130	4700	19020	8320	8320	8250	36220	33290	7050
BKO	790	8880	380	430	1160	1450	1200	1520	4150	2710	2750	2670	5510	9370	1690
BLZ	4020	35280	630	580	1860	4610	1640	2590	8010	4850	3660	5080	31920	13610	6400
BXO	6060	73900	3070	2610	8960	11750	7420	10770	34260	18780	17590	18310	44970	65790	12460
BZV	67100	647460	18700	18550	54220	80760	53140	82780	216200	158160	119200	166800	443150	401890	140830
CAI	6990	103230	3150	2870	11210	28920	8180	10940	47440	19060	29550	18580	62260	111630	13340
CKY	2650	30850	1250	1140	3620	4700	3250	4840	13690	8440	7450	8230	19060	26920	5520
COO	870	8660	350	440	1040	1290	1250	1540	3740	2940	2860	3030	5610	8560	1910
DAR	7160	90350	1450	1270	4400	11810	3620	5700	19410	10450	8310	10720	66690	32740	11750
DKR	230	2830	120	100	370	480	280	390	1400	680	690	660	1710	2640	460
EBB	430	5950	120	100	350	740	280	440	1510	800	650	810	3610	2540	770
FEZ	43400	557010	22390	25190	80540	150080	72570	82580	291880	146490	306310	144330	331150	1120880	91400
FIH	14890	143640	4140	4100	11980	17900	11730	18280	47820	34900	26300	36800	98380	88760	31220
FNA	130	1380	60	60	160	210	150	230	600	390	330	380	860	1180	260
GBE	15630	90180	1830	1790	5330	11690	5120	7920	22190	15210	11910	16380	86570	38950	24570
HRE	25480	196290	3690	3450	10860	25210	9880	15540	46220	29360	22120	31070	179110	79330	41020
JIB	3640	55420	1110	940	3600	11010	2670	4020	16340	7120	7390	7070	35460	29250	6510
JNB	537940	2488950	58160	56500	169990	396710	162110	251440	712720	482080	376400	518290	2971380	1242690	780850
KAN	9720	109790	4610	5050	14220	17720	14380	18710	51070	33230	33000	32580	68060	113500	20740
KGL	7230	93630	1870	1650	5610	11420	4680	7380	24390	13470	10690	13720	58780	41300	13150
KRT	8810	130220	3380	2880	11170	24320	8200	12010	50720	21100	22460	20750	77770	89920	16390
LAD	7040	60210	1680	1720	4850	7320	4950	7530	19240	14630	11360	15840	43660	36220	15150
LBV	10210	100030	3440	3680	10010	13330	10550	15890	38190	31260	23790	33080	66510	76560	22100
LFW	870	8520	340	440	1020	1270	1250	1510	3680	2900	2920	3010	5540	8530	1910
LLW	5510	82010	2010	1710	6560	14750	4850	7200	29800	12680	13050	12500	49080	52260	10140
LUN	9080	74760	1470	1380	4320	9240	3940	6200	18250	11720	8820	12380	62920	31490	15610
MGQ	2530	36640	610	530	1920	6180	1490	2300	8680	4140	3740	4170	25520	14970	4170
MPM	16330	96360	1800	1720	5280	13470	4920	7680	22390	14640	11230	15650	101260	38560	23030
MRU	24820	217250	3440	3040	10480	48720	8670	13710	46640	25390	19800	26410	268840	79040	34810
MSU	0	40570	810	790	2340	5560	2270	3490	9780	6720	5370	7260	41820	17130	11280
NBO	40560	0	9740	8440	29860	74050	24030	37700	132640	68440	56450	69500	367300	223900	69620
NDJ	810	9740	0	360	1200	1560	1010	1450	4540	2520	2380	2450	5930	8850	1660
NIM	790	8440	360	0	1110	1400	1390	1490	3930	2740	3120	2750	5300	9670	1720
NKC	2340	29860	1200	1110	0	5460	3160	4230	15300	7380	8290	7190	17890	32010	4800
NSI	5530	73740	1550	1390	5440	0	3960	5430	23740	9500	46150	9320	62580	60270	8420
OUA	2270	24030	1010	1390	3160	3980	0	4250	11180	7830	9100	7900	15130	27810	4960
ROB	3490	37700	1450	1490	4230	5450	4250	0	15860	11710	9480	11410	23940	32260	7440
SID	9780	132640	4540	3930	15300	23840	11180	15860	0	27690	29500	27040	78810	117220	19310
SSG	6720	68440	2520	2740	7380	9540	7830	11710	27690	0	17540	22710	44510	56990	14510
TIP	5370	56440	2380	3120	8290	46340	9100	9480	29490	17530	0	18040	33990	114070	12200
TMS	7260	69500	2450	2750	7190	9360	7900	11410	27040	22710	18040	0	46430	55990	15890
TNR	41820	367350	5930	5300	17890	62860	15130	23940	78830	44520	34000	46430	0	132950	60410
TUN	17130	223890	8850	9670	32010	60520	27810	32260	117220	56990	114070	55980	132920	0	35720
WDH	11280	69640	1660	1720	4800	8460	4960	7440	19320	14520	12200	15890	60420	35730	0

D. Default values

Appendix IV gives the default values of all the aircraft types that will be used in the model.

AIRCRAFT CHARACTERISTICS	Erj 135 JET	F 50	737-200	737-400	A320-200	A340 200	737-800	767-200	747-200	767-300ER	747-400
Cruising Speed (Kph)	833	448	760	815	833	861	810	850	895	897	914
Passenger Capacity	37	56	130	168	180	295	189	255	291	290	401
ToGWmax (Kg)	21 100	19 950	52 437	68 040	73 500	27 500	78 240	136 985	374 850	181 890	390 100
Max fuel Capacity (US gal)	5 187	1 357	5 163	5 701	6 300	36 984	6 878	16 700	53 858	24 140	48 445
Engine type	AE3007	PW125B	JT8D-15A	CFM 56-	CFM56-	CFM56-	CFM56-	CF6-80A	RB211-	CF6-	PW 4056
Engine maximum thrust (Ibf)	7 400	5 000	16 000	22 000	25 000	31 200	24 000	48 000	53 000	61 500	47 000
Maximum Cruise Fuel Consumption (lb/hr/engine)	2 248,4	751,3	8 811	7 275,4	7 040,0	15 664	4 811	11 033	28 578	11 376	25 014
Maximum range (Km)	3 019	1 300	3 700	3 810	5 615	13 500	5 670	12 250	7 900	12 500	13 480
Number of Engines	2	2	2	2	2	4	2	2	4	2	4
Crew Number	5	5	6	7	7	8	7	7	8	8	8
DEFAULT VALUES											
Usable Hours in an operating day	14	14	14	14	14	14	14	14	14	14	14
Operating weeks in a year	52	52	52	52	52	52	52	52	52	52	52
Air manouveur time (hrs)	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10
Ground manouveur time (hrs)	0,25	0,25	0,25	0, 25	0,25	0,25	0,25	0,25	0,25	0,25	0,25
Aircraft servicing time (hrs)	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90	0,90
Depreciation period (years)	9	9	9	15	15	15	15	15	15	15	15
Residual Value (%)	10	10	10	10	10	10	10	10	10	10	10
Interest rate (%)	8	8	8	8	8	8	8	8	8	8	8
Annual insurance rate (%)	3	3	3	3	3	3	3	3	3	3	3
Fuel Density (Ibs/US gal)	6,7	6,7	6,7	6,7	6,7	6,7	6,7	6,7	6,7	6,7	6,7
Cost of fuel (US$/US gal)	0,895	0,895	0,895	0,895	0,895	0,895	0,895	0,895	0,895	0,895	0,895
Oil Cost (US$/US gal)	0,932	0,932	0,932	0,932	0,932	0,932	0,932	0,932	0,932	0,932	0,932
COLLECTED DATA											
Capital Cost of aircraft (US$ million)	19	29	42	48	51	121	56.5	87	150	197	185
Maximum cruise Fuel Consumption (US gal/hr)	671,2	224,3	2 630,1	2 171,8	2 101,5	9 351,6	1 436,5	3 293,4	1 7061,5	3 395,9	14 933,7
Oil consumption (US gallons/hour)	33,56	11,21	131,51	108,59	105,07	467,58	71,81	164,67	853,07	169,79	746,69
Passenger service charge (US$)	6	6	6	6	6	6	6	6	6	6	6
Landing Fees (US$ per single landing)	13	11	296	352	399	1257	399	790	1853	1816	1881
Parking Fees (US$ per 24 hour period)	22	19	37	37	37	76	37	67	96	96	96